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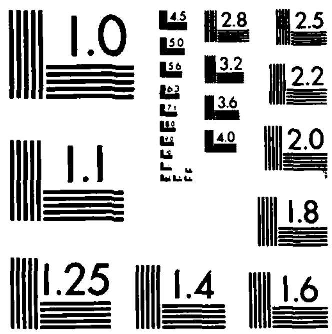
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US ARMY
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ENGINE/AIRFRAME RESPONSE EVALUATION OF THE HH-60A HELICOPTER EQUIPPED WITH THE T700-GE-701 TRANSIENT DROOP IMPROVEMENT ELECTRONIC CONTROL UNIT

USAAEFA

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OCTOBER 1986

FINAL REPORT

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)
Engine/airframe response testing was conducted at Edwards AFB, California (elevation 2302 feet) between 9 June and 25 August 1986. Five flights totaling 11.1 hours were conducted on the HH-60A helicopter and one flight was conducted in the UH-60A helicopter. Four different engine/engine governor configurations were tested. Engine/airframe response tests included jump takeoff, nap-of-the-earth quickstops, power recovery from autorotation, and nap-of-the-earth ridgeline crossing maneuvers. The engine/drive train response was stable for all tests performed. The best configuration for magnitude of main rotor speed droop, rotor speed/power turbine speed droop recovery characteristics, and power turbine speed governing characteristics was the HH-60A with the T700-GE-401 engines equipped with the -401 transient droop improvement engine control unit. The HH-60A with the T700-GE-401 engine equipped with the -701 transient droop improvement engine control unit (with and without the collective potentiometer input) exhibited larger rotor speed droop, noticeable drive train oscillation during droop recovery, and less desirable power turbine speed governing characteristics.

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The undesirable engine/airframe characteristics of the HH-60A with the -701 transient droop improvement engine control unit is a shortcoming. The UH-60A with the T700-GE-700 engine demonstrated the largest main rotor speed droop but residual drive train oscillations were small, droop recovery characteristics were more predictable and power turbine speed governing was noticeably more stable than demonstrated by the T700-GE-401 engines equipped with the -701 transient droop improvement engine control unit. The undesirable engine/airframe response (large main rotor speed droop) of the UH-60A with the T700-GE-700 engines is a previously identified shortcoming. Future designs for the UH-60 engine control units should include all the transient droop improvements of the -401 transient droop improvement engine control unit. Additionally, future designs of engine control units should have dynamics tailored to the particular helicopter in which the engines are to be installed.

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INTRODUCTION

BACKGROUND

1. The US Army has expressed a desire to install T700-GE-701 engines in the UH-60A helicopter to provide added performance margin. To provide commonality with the AH-64A, the UH-60A engines would be equipped with the T700-GE-701 transient droop improved electronic control units (-701 TDI ECU) and hydromechanical units (HMU). However, there is concern that with this engine change the engine/drive train response of the UH-60A may be degraded. As the -701 engine has yet to be installed in an Army UH-60A, the best available test article is the US Air Force HH-60A, which is equipped with T700-GE-401 engines. The US Army Aviation Systems Command requested (ref 1, app A) the US Army Aviation Engineering Flight Activity (USAAEFA) to conduct an evaluation of the US Air Force HH-60A helicopter equipped with the T700-GE-401 engines modified with the -701 TDI ECU and HMU. Additionally, USAAEFA evaluated the HH-60A with -401 TDI ECU and a US Army UH-60A with the T700-GE-700 engine with the standard -700 ECU and HMU.

TEST OBJECTIVE

2. The objective of the test was to evaluate the engine/drive train stability and transient rotor speed droop characteristics of the HH-60A helicopter equipped with the T700-GE-401 engines modified with the installation of the -701 TDI ECU and HMU.

DESCRIPTION

3. The HH-60A helicopter is an Air Force version of the US Army UH-60A. The HH-60A and UH-60A are described in references 2 and 3, respectively. The rotor and drive train systems are the same on both aircraft and therefore, the results of this testing on the HH-60A should be valid for the UH-60A also. The HH-60A and the AH-64A helicopter use the same HMU. The -701 TDI ECU incorporates a three-Hertz notch filter, a collective position signal, and modified torque and power turbine speed values for power turbine governor gain switching. The HH-60A TDI ECU incorporates a collective position signal and a rotor speed signal to improve rotor speed droop characteristics. The dynamics of the two ECUs are different to accommodate the different rotor/drive train dynamics of the AH-64A and HH-60A aircraft. The UH-60A ECU does not incorporate a collective signal nor a rotor speed signal. A further description of the HMU and ECU can be found in appendix B.

TEST SCOPE

4. This evaluation was conducted at Edwards AFB, California, between 9 June and 25 August, 1986. Five flights were conducted on the HH-60A for a total of 11.1 hours. Because the Army test pilots were not qualified in the Air Force HH-60A, and because the aircraft was under the operational control of the Air Force, an Air Force instructor pilot was in the left seat for all HH-60A flights. The HH-60A aircraft was flown at an engine start gross weight and longitudinal center of gravity (cg) of 20,375 pounds and fuselage station (FS) 352.5, respectively. Tests were conducted at field elevation (2302 feet), 6000 and 10,000 feet, pressure altitude. A one hour flight was flown in the UH-60A. The UH-60A tests were flown by an Army crew at field elevation and 6000 feet, pressure altitude. Takeoff gross weight was 17580 pounds at a longitudinal cg of FS 354.6.

TEST METHODOLOGY

5. The engine/drive train stability and engine/airframe response were evaluated using collective steps and pulses, jump takeoffs, NOE quickstops, and recoveries from autorotation. Test techniques are described in the results and discussion section of this report. Data were obtained from calibrated test instrumentation and recorded on magnetic tape. A detailed listing of the test instrumentation is contained in appendix C.

RESULTS AND DISCUSSION

GENERAL

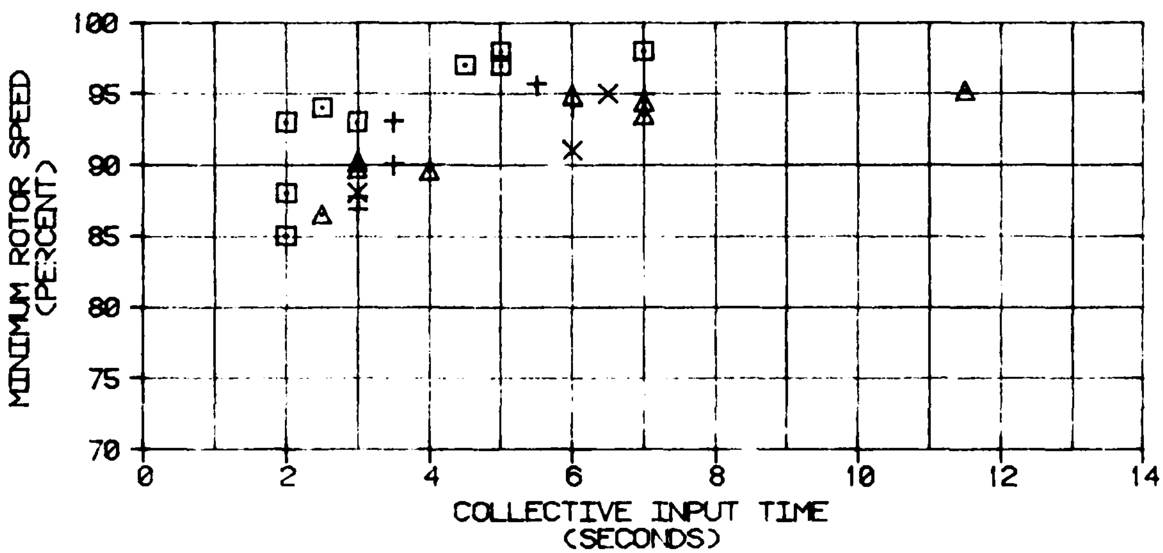
6. Three configurations of the US Air Force HH-60A helicopter equipped with the T700-GE-401 engines were evaluated to determine engine/drive train stability and transient main rotor speed (N_R) droop characteristics. The following configurations are described in the order in which they were evaluated. The first configuration was obtained by modifying the engines with the installation of the -701 TDI ECU and HMU. The second configuration was identical to the first configuration except for the addition of a collective control potentiometer signal to the ECU. For the third configuration, the engines were equipped with the -401 TDI ECU which incorporates a collective control potentiometer signal and N_R signal to the ECU. The -701 TDI HMU was used for all HH-60 testing. Additionally, the US Army UH-60A with the T700-GE-700 engine was evaluated for comparison and will be referred to as the fourth configuration. The low rotor speed warning horn and light is designed to illuminate when N_R drops below 94% for all configurations. The undesirable engine/airframe response of configurations one, two and four during power application from a low torque condition and during nap-of-the-earth (NOE) quickstop maneuvers is a shortcoming.

7. Engine airframe response tests included jump takeoffs, NOE quickstops, power recoveries from autorotation, and NOE ridgeline crossing maneuvers. The engine/drive train was stable for all configurations tested (i.e., all oscillations were damped). The best configuration for magnitude of N_R droop, rotor speed/power turbine speed (N_R/N_P) droop recovery characteristics, and N_P governing was the T700-GE-401 engines with -401 TDI ECU (third configuration). The first and second configurations (T700-GE-401 engines with the -701 TDI ECU and HMU) exhibited larger N_R droop for the same collective input time (fig. A), noticeable drive train oscillation during N_R/N_P droop recovery, and less desirable N_P governing characteristics. Following the flight tests of configuration one, the engine load demand spindles were found misrigged. The load demand spindles were rerigged prior to configuration two testing, but no significant improvement in engine response was apparent. The UH-60A with T700-GE-700 engines demonstrated the largest N_R droop but residual drive train oscillations were reduced from configurations one and two. N_R/N_P droop recovery characteristics were more predictable, and N_P governing was noticeably more stable than configurations one and two.

FIGURE A
H-60A ROTOR SPEED DROOP

SYM	CONFIGURATION
Δ	NO. 1, HH-60A WITH -701 TDI ECU, NO COLLECTIVE SIGNAL
+	NO. 2, HH-60A WITH -701 TDI ECU, WITH COLLECTIVE SIGNAL
⊡	NO. 3, HH-60A WITH -401 TDI ECU
×	NO. 4, UH-60A WITH -700 ECU

NOTE: DATA OBTAINED DURING COLLECTIVE PULLS TO 95% INTERMEDIATE RATED POWER FROM AUTOROTATION.



ENGINE/AIRFRAME RESPONSE

General

8. Jump takeoffs were performed from the ground with the initial collective control position at full down. Collective control was increased to 95% intermediate rated power (IRP) at several rates (input times varied incrementally from 1 to 5 seconds). NOE quickstops were performed at 50 ft above ground level (AGL) with entry speeds of 60, 80, 100 and 120 knots indicated airspeed (KIAS). The maneuvers were terminated at a stable hover. Power recovery from autorotation was performed from stable 80 KIAS descent (power levers at fly) with collective positioned to maintain 1 to 15% split between N_R and N_P. Collective control was increased to 95% IRP in 2 to 12 seconds during recovery. Ridgeline crossing maneuvers were performed at 100 ft AGL from initial airspeeds of 60, 80, 100 and 120 KIAS using simultaneous cyclic and collective control inputs. No significant N_R droop was observed in the four configurations tested while performing ridgeline crossing maneuvers.

Configuration One

9. Configuration one featured T700-GE-401 engines modified with the -701 TDI ECU and HMU. Engine/airframe response of this configuration was evaluated with the maneuvers described in paragraph 8. Time history data are presented in figures 1A through 5E, appendix D. A maximum of 3% N_R droop was observed during jump takeoffs, but 5 to 10% torque splits and torque reversals between number one and number two engines occurred during collective control increases. These torque splits and torque reversals persisted for as much as 8 seconds after the collective control movement was stopped (fig. 1B). Power recovery from autorotations resulted in larger N_R droops and increased engine and airframe oscillations. A 7 second collective control increase to 95% IRP with less than 5% N_R/N_P split resulted in a 5.5% N_R droop, activating the low rotor rpm warning horn and light, followed by a 4.5% N_R overshoot prior to reaching 95% IRP. Residual oscillations persisted for 3 seconds after collective control movement stopped (fig. 2, app D). An extremely slow (11 second) collective control increase with 10% N_R/N_P split resulted in a 5% N_R droop and 3.5% N_R overshoot prior to reaching 95% IRP (fig. 3A). Residual oscillations persisted for 5 seconds after the initial N_R overshoot. More aggressive collective control increase (2 seconds to 95% IRP) resulted in N_R droop to 90%, but the N_R recovery was improved over the slower collective control increase in that N_R/N_P overshoot and residual oscillations were reduced (fig. 4A). The recovery is

inconsistent with the previous examples (figs. 2A through 2C and 3A through 3C) since the pilot will expect a more aggressive collective control increase and larger N_R droop to result in degraded recovery characteristics. These oscillations during recovery occur after the TDI circuit (described in fig. 3, app B) is disabled (i.e., engine torque is above 50 ft-lb). The data indicates that recovery characteristics are improved when collective control input terminates not more than 0.5 seconds after the maximum N_R droop occurs.

10. Poor N_P governing, large N_R droop, and persistent residual engine/airframe oscillations were observed during quickstop maneuvers. During the deceleration to a quickstop, N_P and N_R remained joined up to 104% (fig. 5A, app D). A clean N_R/N_P split did not occur until 5 seconds after collective reduction was initiated. During collective control increase, N_R drooped to 92% activating the low N_R warning horn and light. N_R/N_P overshot to 106% during the final portion of the maneuver while the aircraft was slowing to a stop. Poor N_P governing, torque splits and reversals, unpredictable and inconsistent N_R/N_P droop recovery (para 9) and residual engine/airframe oscillations will make it difficult to safely perform NOE maneuvers such as quickstops and recovery from low power descents with reduced visual cues (e.g., flying at night using pilot night vision systems). The pilot will be required to direct his attention inside the cockpit to compensate for the rapidly changing aural and visual cues (cockpit torque and N_R/N_P indicators) resulting from engine, rotor, and airframe oscillations. This will reduce the NOE maneuvering capability of the aircraft. The undesirable engine/airframe response with the -701 TDI ECU (without collective potentiometer signal) during power application from a low torque condition and during NOE quickstop maneuvers is a shortcoming.

Configuration Two

11. Configuration two was identical to configuration one except for the addition of a collective control potentiometer signal to the ECU. Engine/airframe response of this configuration was evaluated with the maneuvers described in paragraph 8. Time history data are presented in figures 6A through 10E, appendix D. No N_R droop was observed during jump takeoffs, but a torque split between number one and number two engines of more than 15% persisted for over 4 seconds after collective control movement stopped (fig. 6B). A 3 second collective control increase to 95% IRP during power recovery from autorotation with an 11% N_R/N_P split resulted in N_R droop to 93% which activated the low N_R warning horn and light (figs. 7A through 7C). One N_R/N_P overshoot to 102.5% was observed during recovery. A 6 second collective control increase with a 2% N_R/N_P split resulted in a smaller

N_R droop to 95% (figs. 8A through 8C). An unintentional reduction in rate of collective control increase during the last two seconds resulted in degraded recovery characteristics in that N_R/N_P overshot to 103.5% and several residual engine/airframe oscillations ocurred. Addition of the collective control potentiometer signal improved the magnitude of N_R droop for a given rate of collective control input but this configuration demonstrated the same trends as configuration one in torque splits and unpredictable N_R/N_P recovery characteristics. The addition of the collective potentiometer signal to the ECU had no effect on the torque and N_R/N_P oscillations since they occurred when the TDI circuitry was disabled (i.e., above 50 ft-lb engine torque).

12. Poor N_P governing, large N_R droop, and persistent residual engine/airframe oscillations were observed during quickstop maneuvers. During deceleration to a quickstop, N_R and N_P remained joined up to 104% (fig. 9A, app D). After the N_R/N_P split, N_P continued to increase to 105% followed by N_R droop to 95.5%. No N_R/N_P split occurred during a quickstop with minimum collective control position of 25% and N_R drooped to 98% (figs. 10A through 10E). An 8 to 10% torque split and small persistent engine/airframe oscillations were apparent to the pilot as the aircraft came to a stop. Configuration two with the collective potentiometer signal showed some improvement in magnitude of N_R droop, but demonstrated trends similar to configuration one in torque splits and unpredictable N_R/N_P droop recovery characteristics. Poor N_P governing, torque splits, unpredictable N_R/N_P droop recovery characteristics (para 11), and residual engine/airframe oscillations will make it difficult to safely perform NOE maneuvers such as quickstops and recovery from low power descent with reduced visual cues (e.g, flying at night using pilot night vision systems). The pilot will be required to direct his attention inside the cockpit to compensate for rapidly changing aural and visual cues (cockpit torque and N_R/N_P indicators) resulting from engine, rotor, and airframe oscillations. This will reduce NOE maneuvering capability of the aircraft. The undesirable engine/ airframe response with the -701 TDI ECU (with collective potentiometer signal) during power application from a low torque condition and during NOE quickstop maneuvers is a shortcoming.

Configuration Three

13. Configuration three featured the -401 TDI ECU, described in appendix B which incorporated a collective control potentiometer signal and N_R signal to the ECU. This configuration was evaluated with the maneuvers described in paragraph 8. Time history data are presented in figures 11A through 12E, appendix D. During jump

takeoffs, N_R droop was minimum and the torque splits observed on the previous two configurations did not occur. During recovery from autorotation, an aggressive 1.5 second collective control increase to 95% IRP with a 10% N_R/N_P split resulted in N_R droop to 87.5% with only one overshoot to 102% during recovery (figs. 11A through 11C). There was no degradation in N_R/N_P recovery characteristics with slower collective control increases or smaller N_R/N_P splits at the initiation of the collective control increase. During an aggressive quickstop maneuver, N_R drooped to 91.5% with one overshoot to 102% during recovery (figs. 12A through 12E). N_R droop and N_R/N_P recovery characteristics were predictable with changes in maneuver aggressiveness. During all maneuvers, configuration three demonstrated noticeably less N_R droop, good N_P governing, good N_R/N_P droop recovery characteristics, and minimum residual engine/airframe oscillations. The reduced magnitude of N_R droop can be attributed to the addition of an N_R signal to the TDI circuit in the ECU. Future designs of UH-60A engine control units should include all the transient droop improvements of the -401 TDI ECU. The better recovery characteristics of the -401 TDI ECU (reduced oscillations) occur when the TDI circuit is disabled. Therefore, the better recovery characteristics must be attributed to the different N_P governor dynamics shown in figure 5, appendix B. The dynamics of the -701 TDI ECU were developed for the AH-64A helicopter. In future designs, the dynamics of the engine N_P governor should be tailored to the helicopter in which the engine is to be installed. The engine/airframe response characteristics of the HH-60A with the -401 TDI ECU are satisfactory.

Configuration Four

14. Configuration four was the UH-60A equipped with the T700-GE-700 engines. Engine/airframe response of this configuration was evaluated with the maneuvers described in paragraph 8. Time history data are presented in figures 13 through 16, appendix D. A jump takeoff performed with a 1.5 second collective control increase to 95% IRP resulted in N_R droop to 96.5% and one overshoot to 102.5% during N_R/N_P recovery (fig. 13). A torque split between number one and number two engines persisted for 6 seconds after collective movement stopped. Autorotation with a 4.0 second collective control increase to 95% IRP resulted in N_R droop to 88% and one overshoot to 102% during N_R/N_P recovery (fig. 14). The torque split during N_R/N_P recovery was similar to that described for jump takeoffs. For a given rate of collective control input, the magnitude of N_R droop was larger in this configuration than the other three configurations, but the N_R/N_P droop recovery was more predictable than configurations one and two. The dynamics in the UH-60A N_P governor are the same as the

-401 TDI ECU and N_R/N_P recovery characteristics are good in both configurations.

15. During quickstop maneuvers, good N_P governing and good N_R/N_P droop recovery characteristics were observed. During an aggressive quickstop maneuver N_R drooped to 85% with one overshoot to 101.5% during N_R/N_P recovery (fig. 15, app D). A moderately aggressive quickstop resulted in N_R droop to 94%, activating the low N_R warning horn and light, with one overshoot to 102% (fig. 16). For a given rate of collective control increase, the magnitude of N_R droop was larger in this configuration than the other configuration tested. During all the maneuvers, the N_R/N_P droop recovery characteristics were predictable and fewer residual engine/airframe oscillations were apparent to the pilot. Torque splits occurred during all maneuvers but were less noticeable to the pilot because the return to matched torque and steady state torque conditions occurred more smoothly in this configuration than configurations one and two. Large N_R droop resulting in activation of the low N_R warning system and moderate residual engine/airframe oscillations will limit aggressive combat maneuvering tactics. The undesirable engine/airframe response (large N_R droop) in the UH-60A with T700-GE-700 engines during power application from a low torque condition and during NOE quickstop maneuvers is a previously identified shortcoming.

ENGINE/DRIVE TRAIN STABILITY

16. Tests of engine/drive train stability were conducted in configuration one. Ground tests consisted of pulling up on collective to get the aircraft light on the wheels, rapidly dropping the collective control 10%, holding for 5 seconds, then rapidly pulling the collective up 10% and holding for 5 seconds. The collective was also cycled $\pm 5\%$ at 2 to 3 Hertz and then held steady for 5 seconds. The collective oscillations were repeated at a 300-foot hover. The engine/drive train response was well damped. No residual oscillations were noted. The engine/drive train stability of the HH-60A with the -701 TDI ECU is satisfactory.

CONCLUSIONS

GENERAL

17. The dynamics of the -701 TDI ECU N_P governor (AH-64A configuration) degrade the power turbine speed governing of the HH-60A when compared to either the -401 TDI ECU (HH-60A configuration) or the UH-60A with the T700-GE-700 engines (paras 13 and 14).

18. The HH-60A with the -401 TDI ECU exhibited the least transient N_R droop and the best N_R/N_P recovery characteristics and is satisfactory (para 7).

19. The TDI circuits in the -401 TDI ECU decrease the magnitude of transient rotor speed droop (para 13).

20. The engine/drive train response is stable with the -701 TDI ECU in the HH-60A.

21. The UH-60A with T700-GE-700 engines exhibited large transient N_R droop but N_R/N_P recovery characteristics were comparable to the HH-60A with the -401 TDI ECU (para 7).

22. The HH-60A with the -701 TDI ECU (with and without collective potentiometer input) exhibited the least desirable N_P governing characteristics (large N_R droop and poor N_R/N_P recovery) (para 7).

SHORTCOMINGS

23. The following shortcomings were found:

a. The undesirable engine/airframe response of the HH-60A with -701 TDI ECU (with and without collective potentiometer input) during power application from a low torque condition and during NOE quickstop maneuvers is a shortcoming (paras 10 and 12).

b. The undesirable engine/airframe response (large N_R droop) of the UH-60A with the T700-GE-700 engines during power application from a low torque condition and during NOE quickstop maneuvers is a previously identified shortcoming (para 15).

RECOMMENDATIONS

24. Future designs for UH-60 engine control units should include all the transient droop improvements of the -401 TDI ECU (para 13).

25. Future designs of engine control units should have dynamics tailored to the particular helicopter in which the engines are to be installed (para 13).

APPENDIX A. REFERENCES

1. Letter, AVSCOM, AMSAV-8, 29 January 1986, subject: HH-60A Helicopter Equipped with the T700-GE-701 Transient Droop Improvement Electronics Control Unit. (Test Request)

2. Technical Order, TO 1H-60(H)A-1, *Preliminary Flight Manual, HH-60A Helicopter*, Headquarters Department of the Air Force, 16 August 1985.

3. Technical Manual, TM 55-1520-237-10, *Operator's Manual, UH-60A Helicopter*, Headquarters Department of the Army, 21 May 1979 with change 37 dated 17 July 1986.

APPENDIX B. DESCRIPTION

GENERAL

1. Only one type hydromechanical unit (HMU) was used on the HH-60A during these tests. The HMU on the UH-60A was different. The HH-60A tests were done with -401 transient droop improvement (TDI) electronic control units (ECU) and with -701 TDI ECU (with and without a collective position signal input). The UH-60A tests were done using a third type of ECU, which is standard on the T700-GE-700 engines on the UH-60A.

Hydromechanical Units

2. The acceleration fuel schedules for T700-GE-700 and T700-GE-701 engines are shown in figure 1. The T700-GE-701 HMU used is known as the TDI HMU because the acceleration fuel schedule was raised above approximately 61% gas producer speed from the previous T700-GE-701 HMU version.

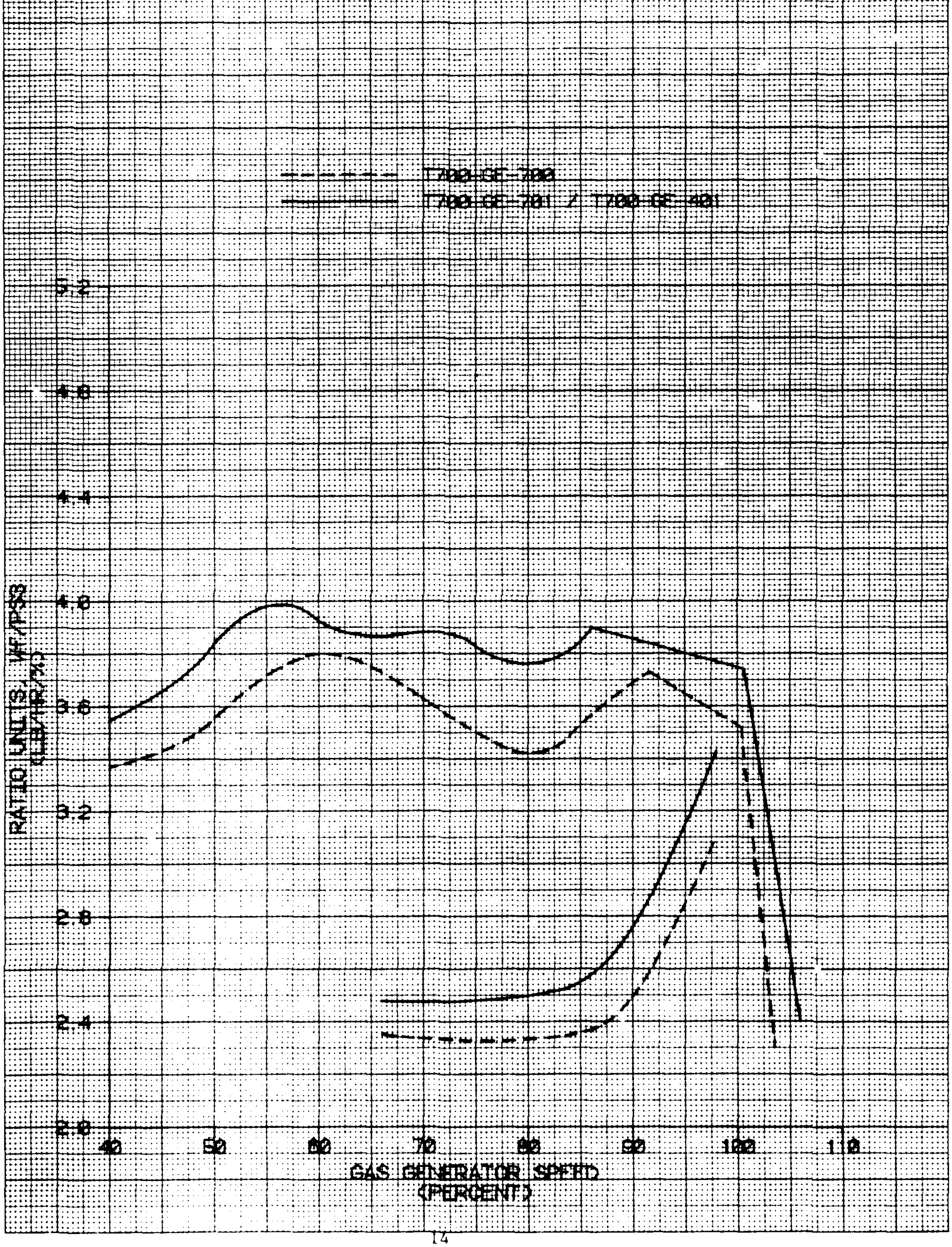
Electrical Control Units

3. Figure 2 presents a schematic of the -700 ECU power turbine speed governor. The governor switches from high to low gain at low engine torque when the power turbine speed (Np) is close to 100%. This is to prevent the engine from spooling down rapidly so that it can respond to power demands more quickly. It switches back to high gain if engine torque rises above 20 foot-pounds or Np is above 104% or below 99%.

4. Figure 3 presents a schematic of the -701 TDI ECU Np governor and the cicuitry added to improve the transient rotor speed droop characteristics. The TDI circuitry accepts a collective control position input which it differentiates. It then increases fuel flow as a function of positive collective control rate of movement. This ECU was also tested with the collective signal disabled. The TDI circuitry is disabled if the engine torque is above 50 ft-lb or Np is above 107%. The Np governor gain is switched from low to high if the engine torque is above 50 ft-lb or the Np is above 107% or below 99% (a change from the -700 Np governor).

5. Figure 4 presents a schematic of the -401 TDI ECU Np governor and TDI circuitry. The TDI circuitry increases fuel flow as a function of collective rate of movement and rotor speed decay rate. Differences between the -701 and -401 TDI ECU are highlighted in dashed circles. Table 1 presents the differences among the ECU in Np governor gain switching conditions and input signals.

FIGURE 1
ACCELERATION FUEL SCHEDULE
GENERAL ELECTRIC T700



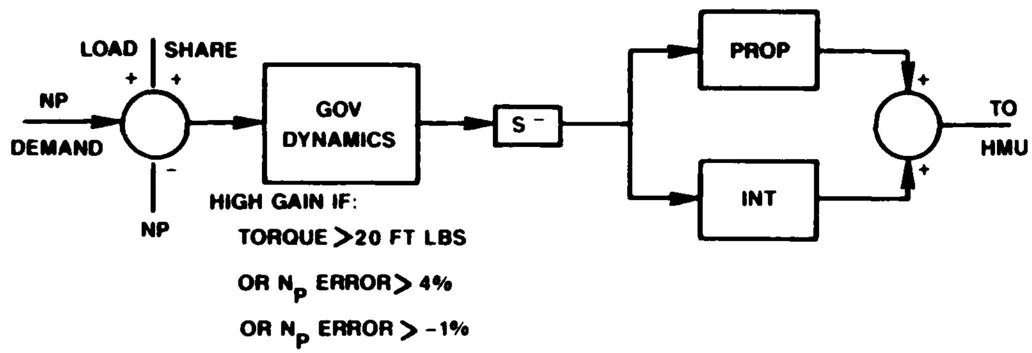


Figure 2. Functional Description of T700-GE-700 ECU

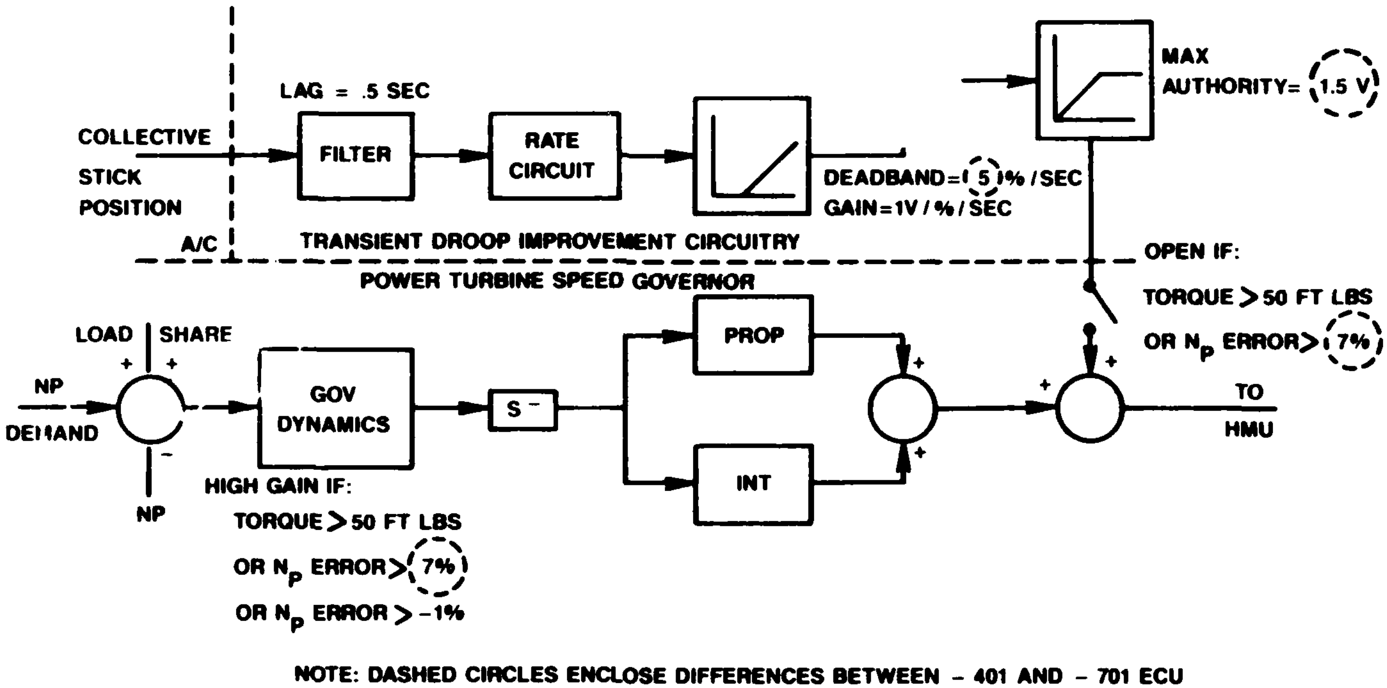
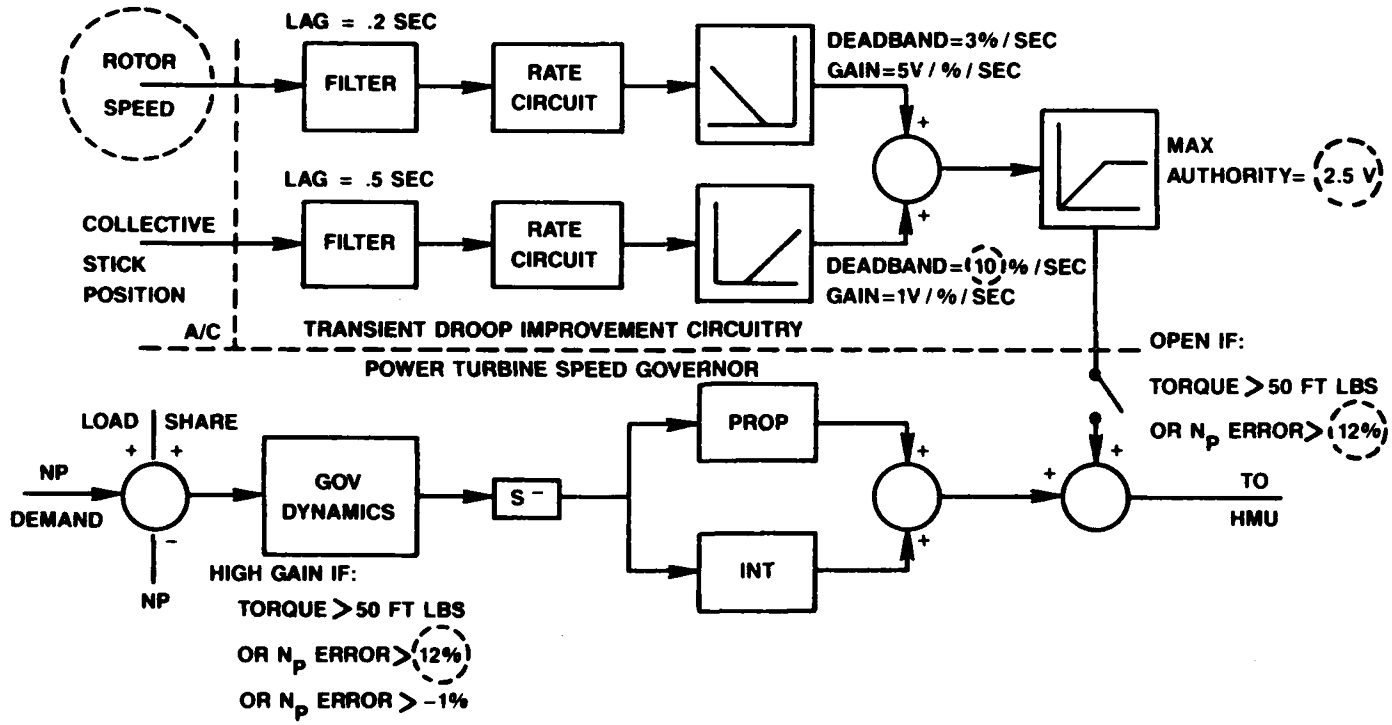


Figure 3. Functional Description of T700-GE-701 ECU



NOTE: DASHED CIRCLES ENCLOSE DIFFERENCES BETWEEN - 401 AND - 701 ECU

Figure 4. Functional Description of T700-GE-401 FCU

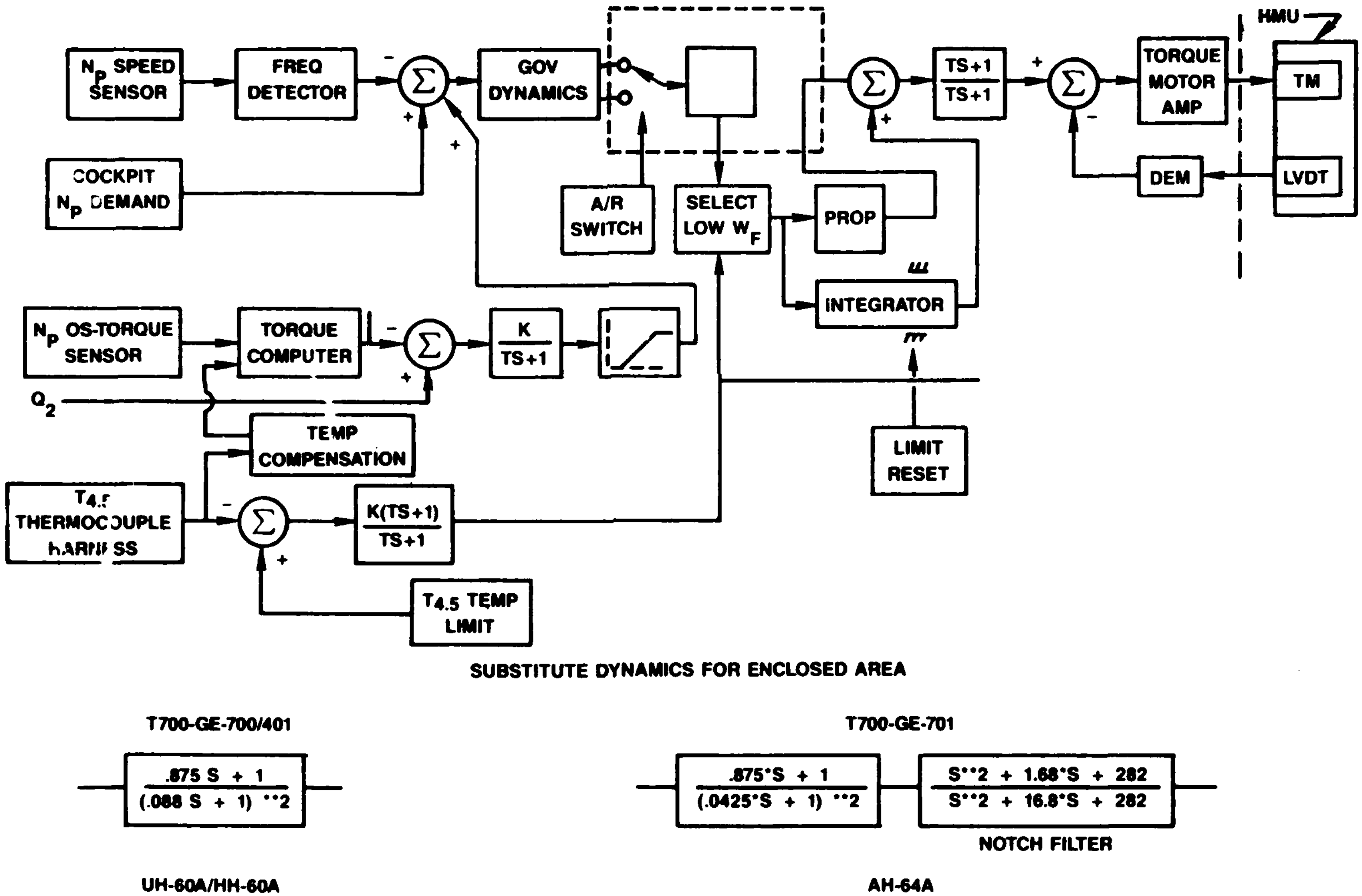


Figure 5. Power Turbine Speed Governor Dynamics Comparison

Table 1. Electrical Control Unit Description

Configuration	Type ECU	Gain Switch Conditions		Input Signals	
		Engine Torque (ft-lb)	Power Turbine Speed (%)	Collective Position	Rotor Speed
One	-701	50	107	No	No
Two	-701	50	107	Yes	No
Three	-401	50	112	Yes	Yes
Four	-700	20	104	No	No

6. Figure 5 shows the difference in dynamics between the -700/-401 TDI ECU and the -701 TDI ECU. The notch filter in the -701 ECU was added to prevent an instability on the AH-64A.

APPENDIX C. INSTRUMENTATION

1. Airborne data acquisition systems were installed on both aircraft. The systems included transducers, wiring, signal conditioning, pulse code modulation (PCM) encoder, magnetic tape recorder, and cockpit displays and controls. A boom was mounted on each aircraft, extending forward of the nose in the water line plane. The booms incorporated pitot-static tubes, and angle-of-attack and angle-of-sideslip sensors.

2. Instrumentation and related special equipment required for the test are presented in the following list.

<u>Pilot Station Displays</u>

Pressure altitude (boom system)
Airspeed (boom system)
Vertical rate of climb (ship system)
Main rotor speed (high resolution)
Engine torque (both engines)
Engine measured gas temperature (both engines)
Engine power turbine speed (both engines)
Engine gas generator speed (both engines)
Engine load demand spindle position (both engines)
Angle of sideslip
Control positions
- Longitudinal
- Lateral
- Directional
- Collective

Radar altitude
Event switch
CG Normal acceleration
Primary attitude indicator
Turn needle and ball

<u>Copilot Station Displays</u>

Pressure altitude (ship system)
Airspeed (ship system)
Main rotor speed
Engine Torque (both engines)
Engine measured gas temperature (both engines)
Engine gas generator speed (both engines)
Fuel used (both engines)
Total air temperature
Time code display
Event switch
Data system controls

Parameters Recorded on Magnetic Tape

Time code
Event (pilot and copilot)
Main rotor speed
Fuel used (both engines)
Engine torque (both engines)
Engine measured gas temperature (both engines)
Engine gas generator speed (both engines)
Engine power turbine speed (both engines)
Engine fuel flow (both engines)
Airspeed (boom system)
Airspeed (ship system)
Pressure altitude (boom system)
Pressure altitude (ship system)
Total air temperature
Control positions
- Longitudinal
- Lateral
- Directional
- Collective

Aircraft attitudes
- Pitch
- Roll
- Yaw

Aircraft angular velocities
- Pitch
- Roll
- Yaw

Radar altitude
CG normal acceleration

APPENDIX D. TEST DATA

INDEX

FIGURE 1A

JUMP TAKEOFF
HH-60A USAF S/N 83-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ECU TYPE
19930	323.3 (MID)	2710	22.0	-701 TDI

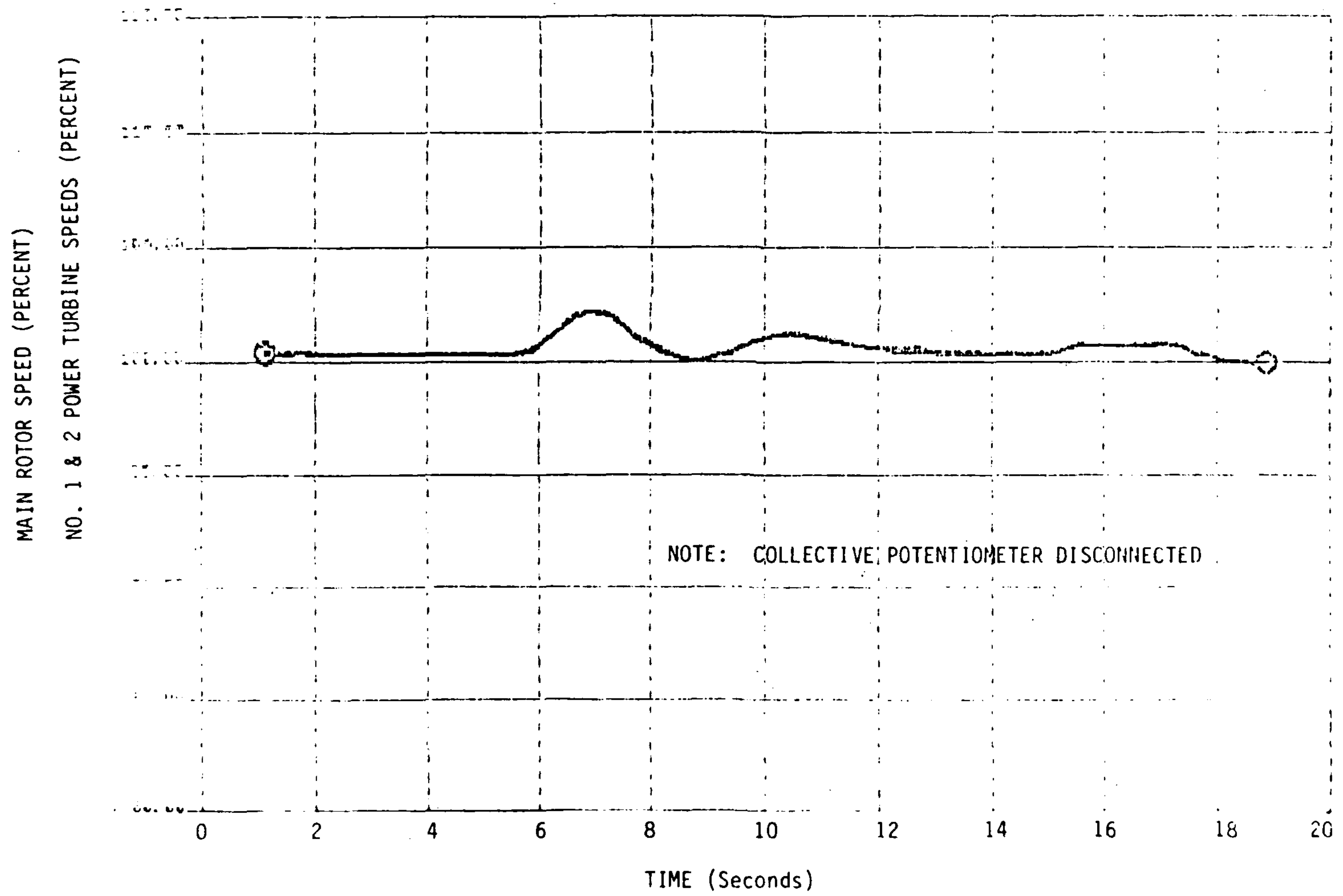


FIGURE 1B

JUMP TAKEOFF
HH-60A USAF S/N 83-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ECU TYPE	CONFIGURATION
19930	353.3(MID)	2710	22.0	-701 TDI	ONE

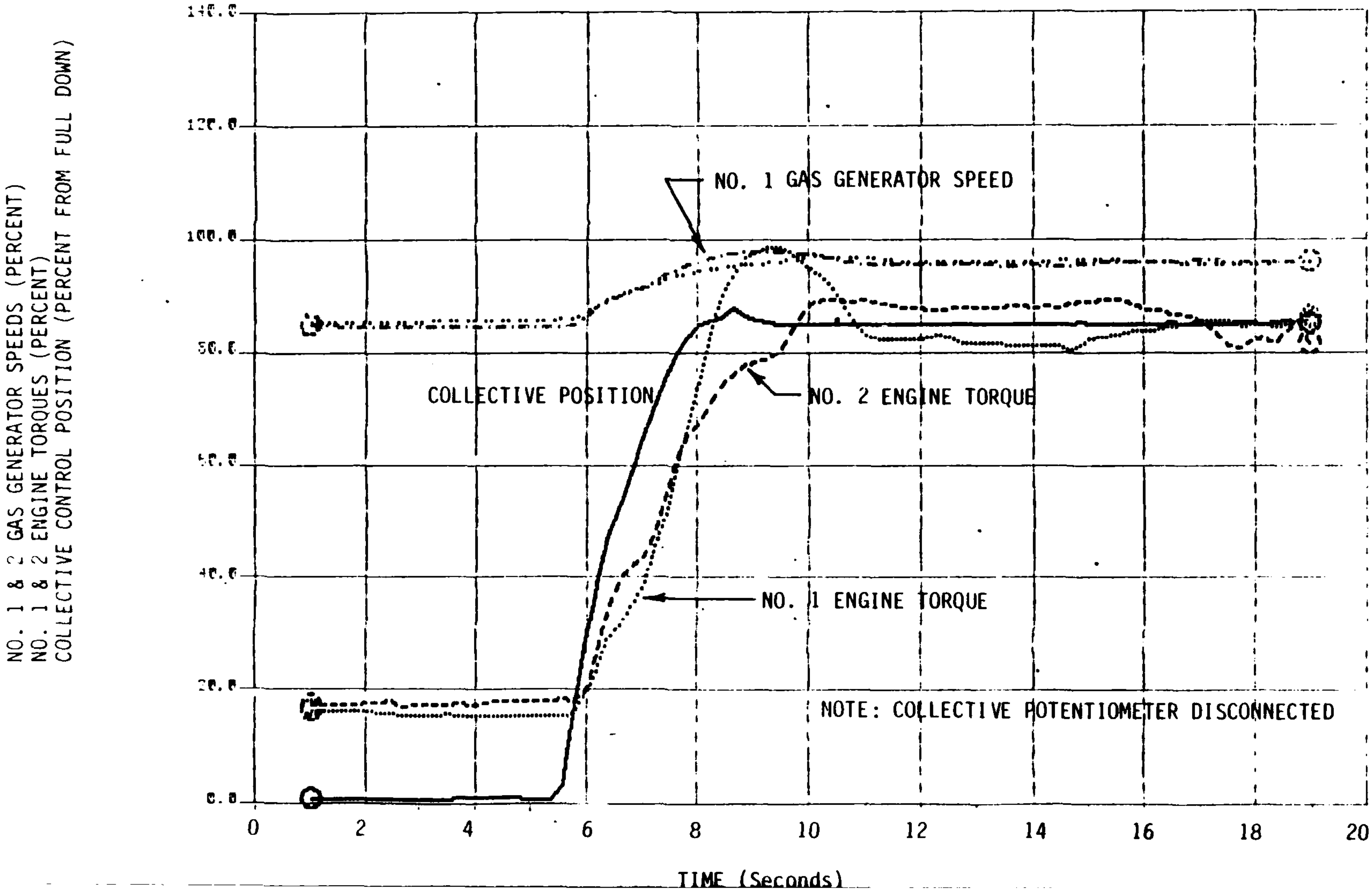


FIGURE 1C

JUMP TAKEOFF
HH-60A USAF S/N 83-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ECU TYPE	CONFIGURATION
19930	353.3(MID)	2710	22.0	-701 TDI	ONE

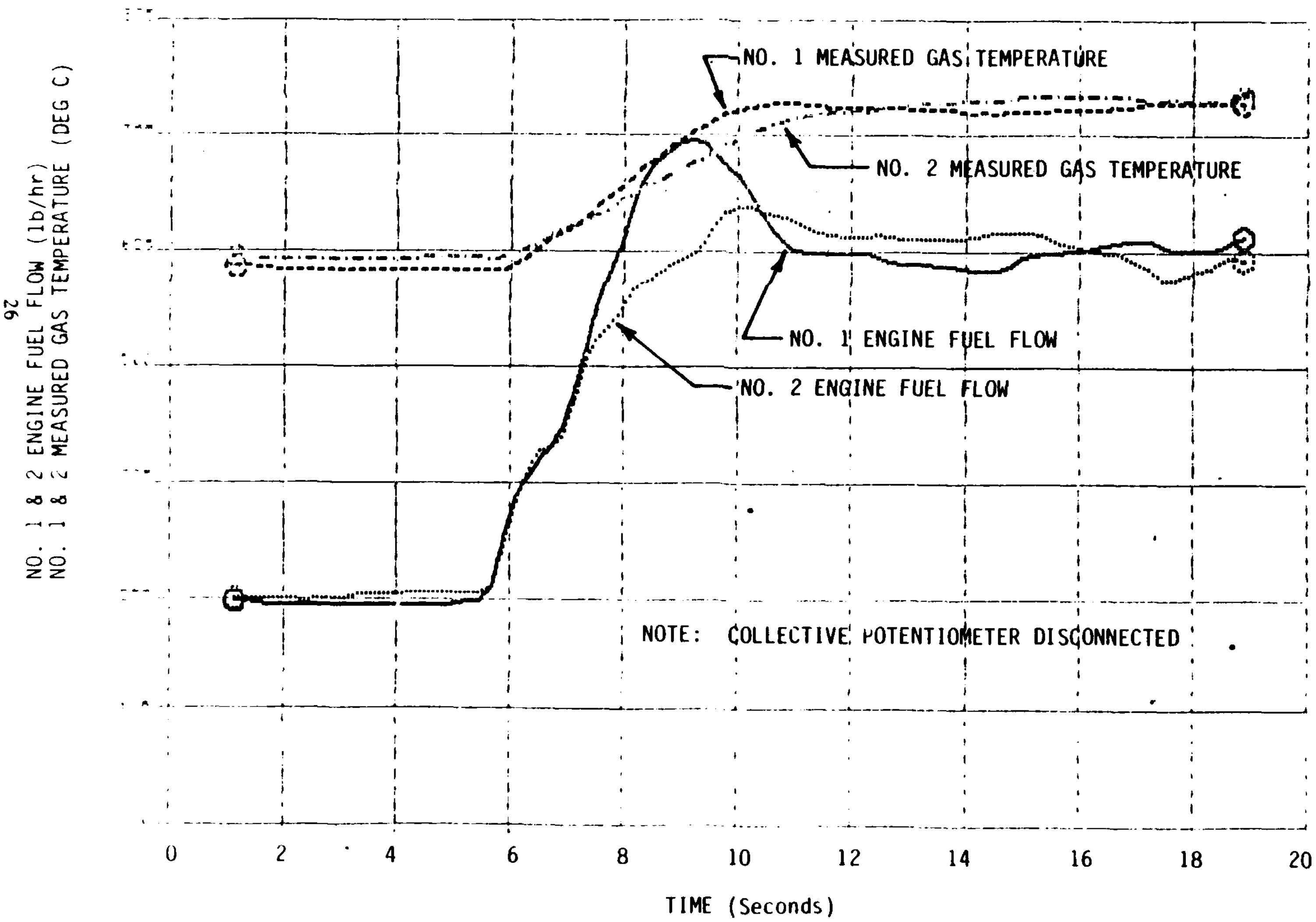


FIGURE 2A

RECOVERY FROM AUTOROTATION

HH-60A USAF S/N 82-718

GROSS WEIGHT (lb)	LONG Cg Location (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
19810	354.5 (MID)	6800	19.0	74	-701 TDI	ONE

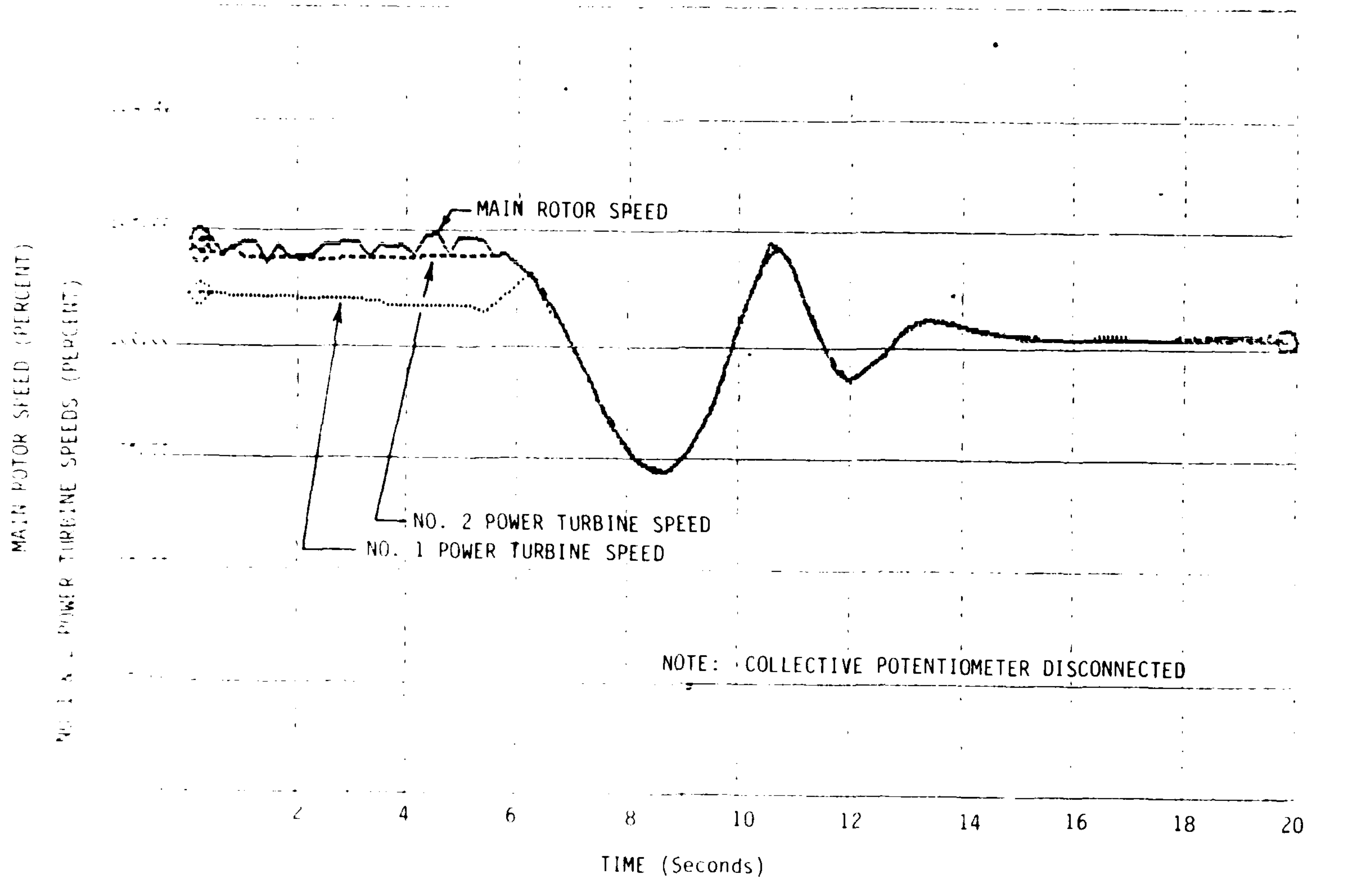


FIGURE 2B

RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
19810	354.5(MID)	6800	19.0	74	-701 TYPE	ONE

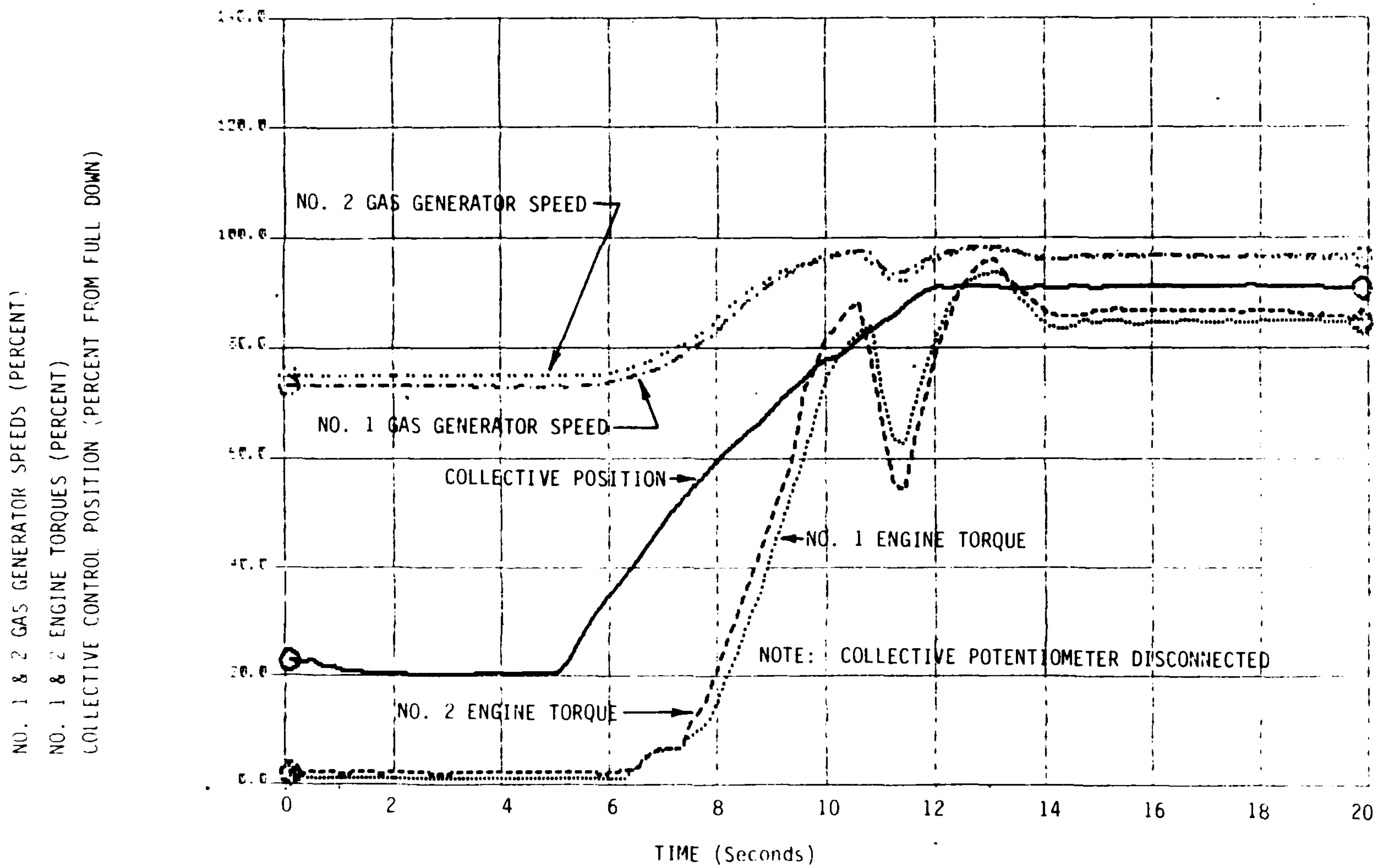


FIGURE 2C
RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

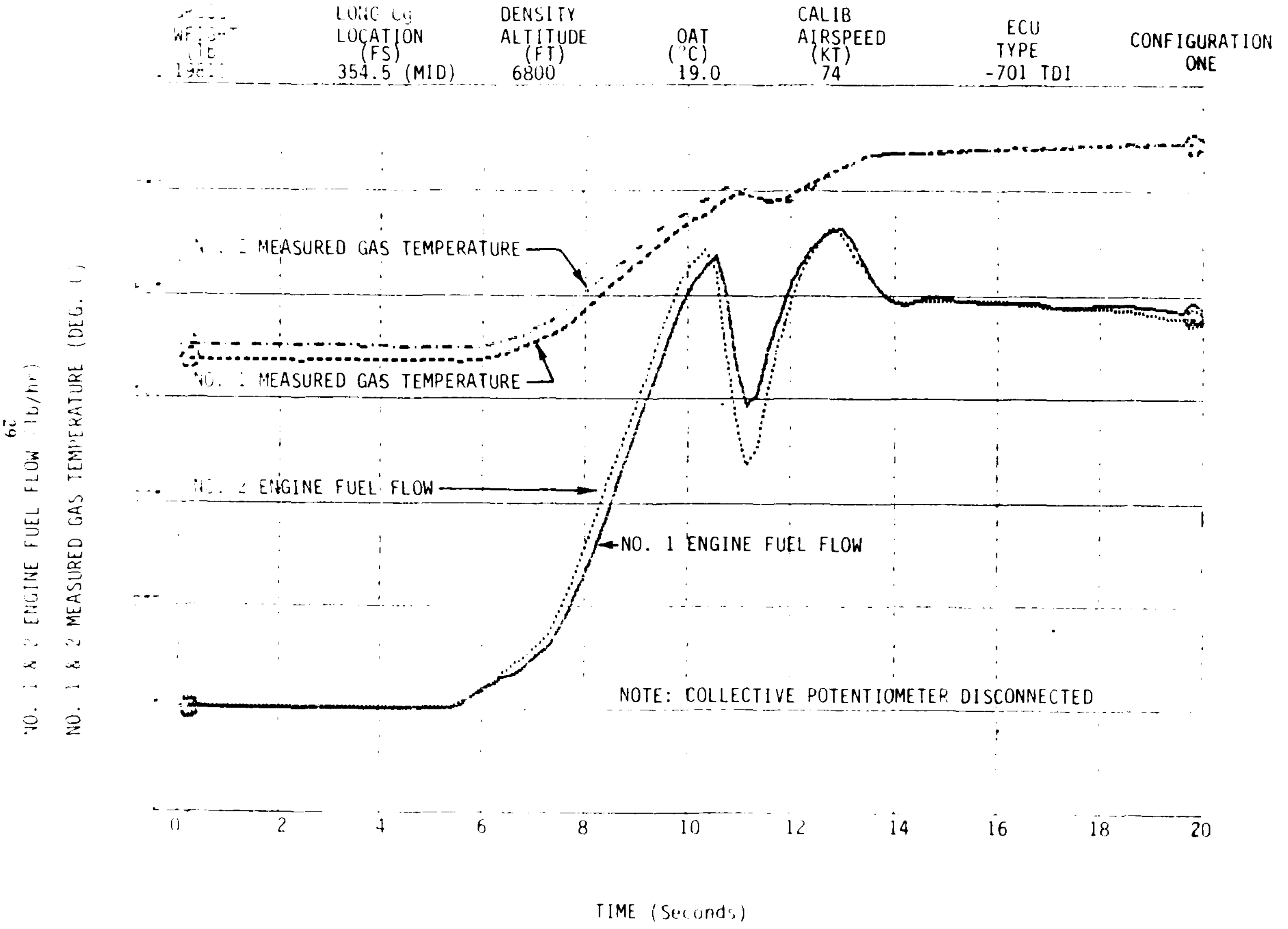


FIGURE 3A

RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
19170	354.8 (MID)	6640	19.0	68	-701 TDI	ONE

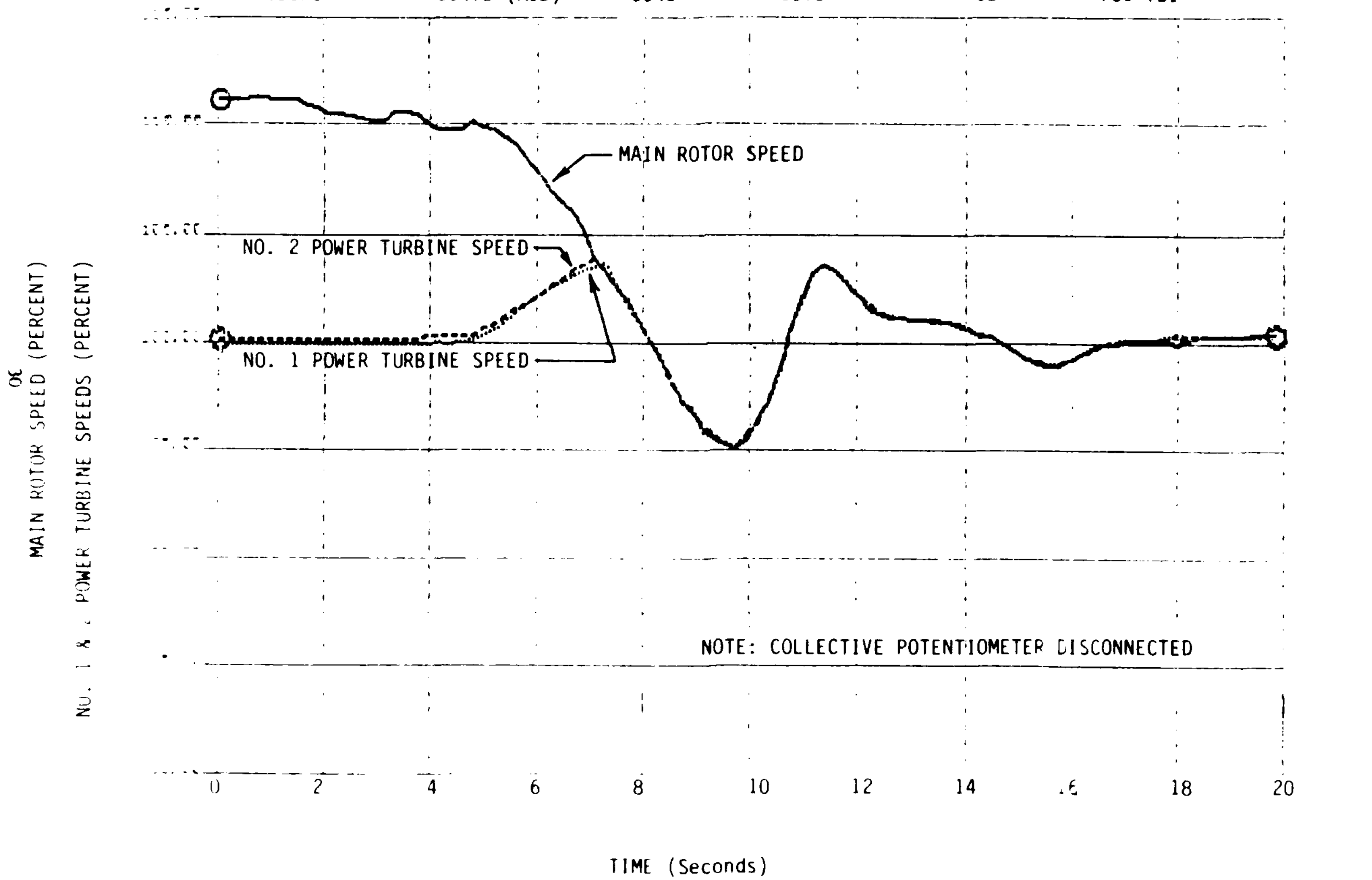


FIGURE 3B

RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
19170	354.8(MID)	6640	19.0	68	-701 TDI	ONE

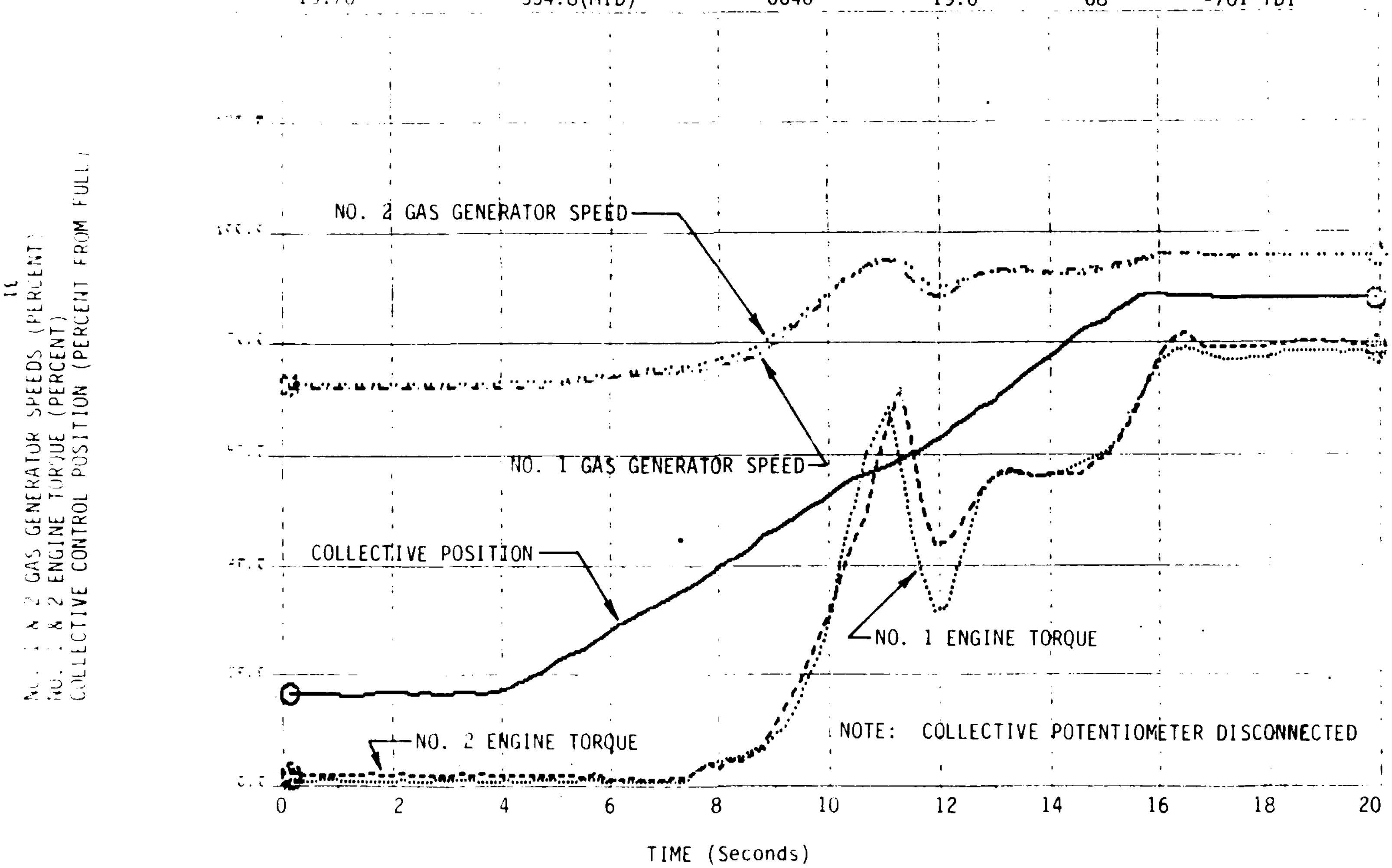


FIGURE 3C

RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
19170	354.8 (MID)	6640	19.0	68	-701 TDI	ONE

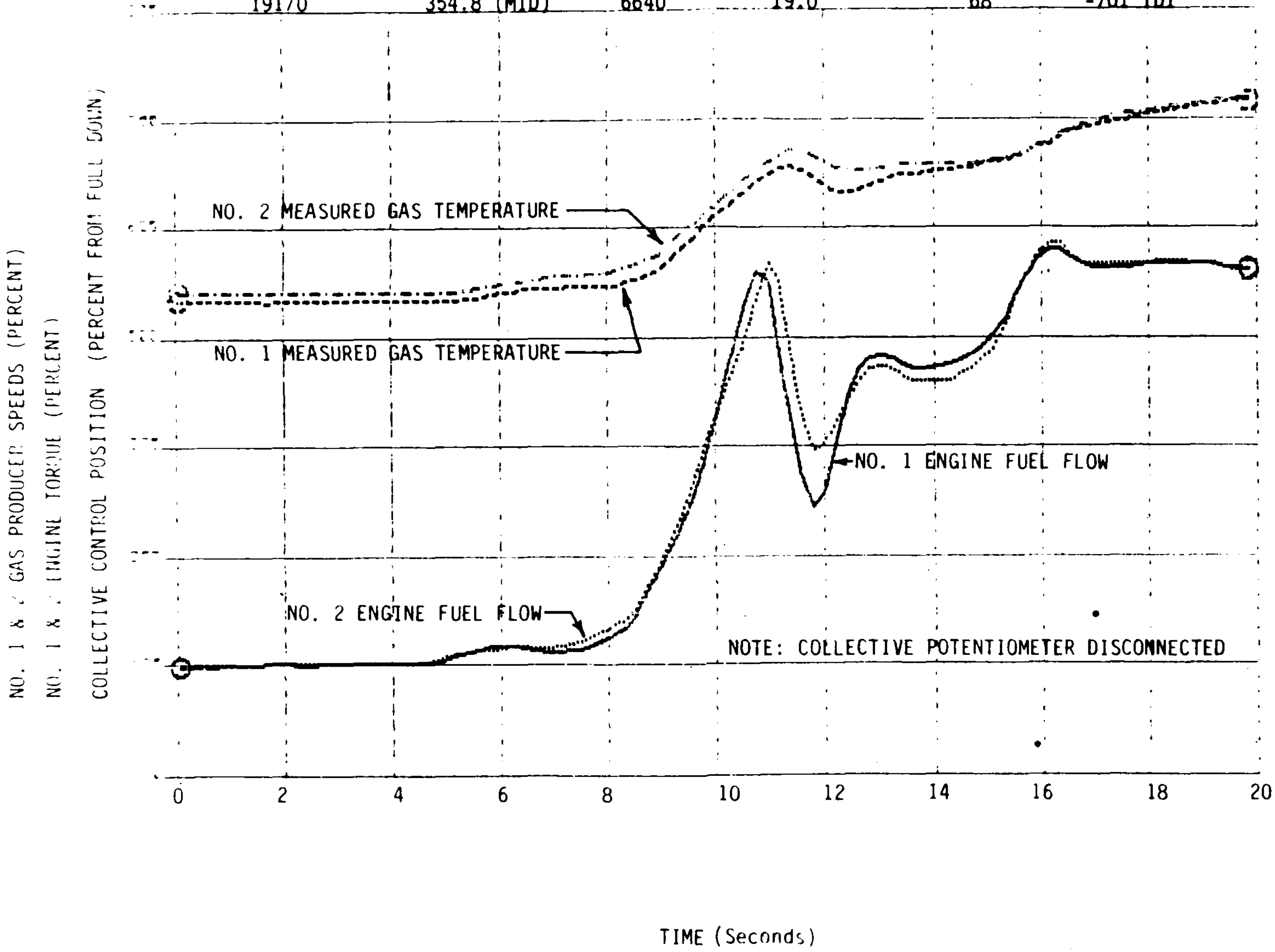


FIGURE 4A

RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
19740	354.6 (MID)	7220	18.0	78	-701 TDI	ONE

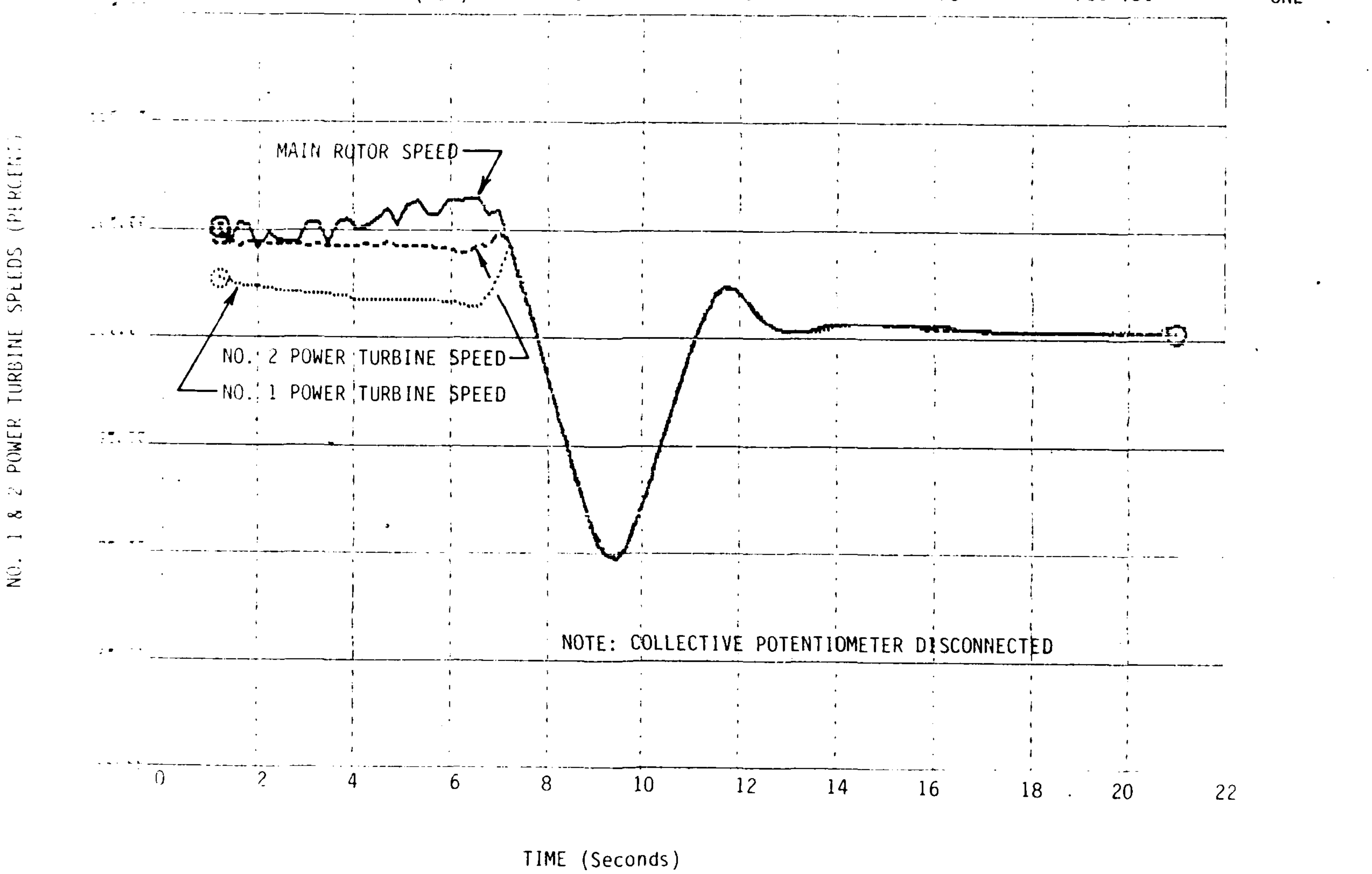


FIGURE 4B

RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
19740	354.6(MID)	7220	18.0	78	-701 TDI	ONE

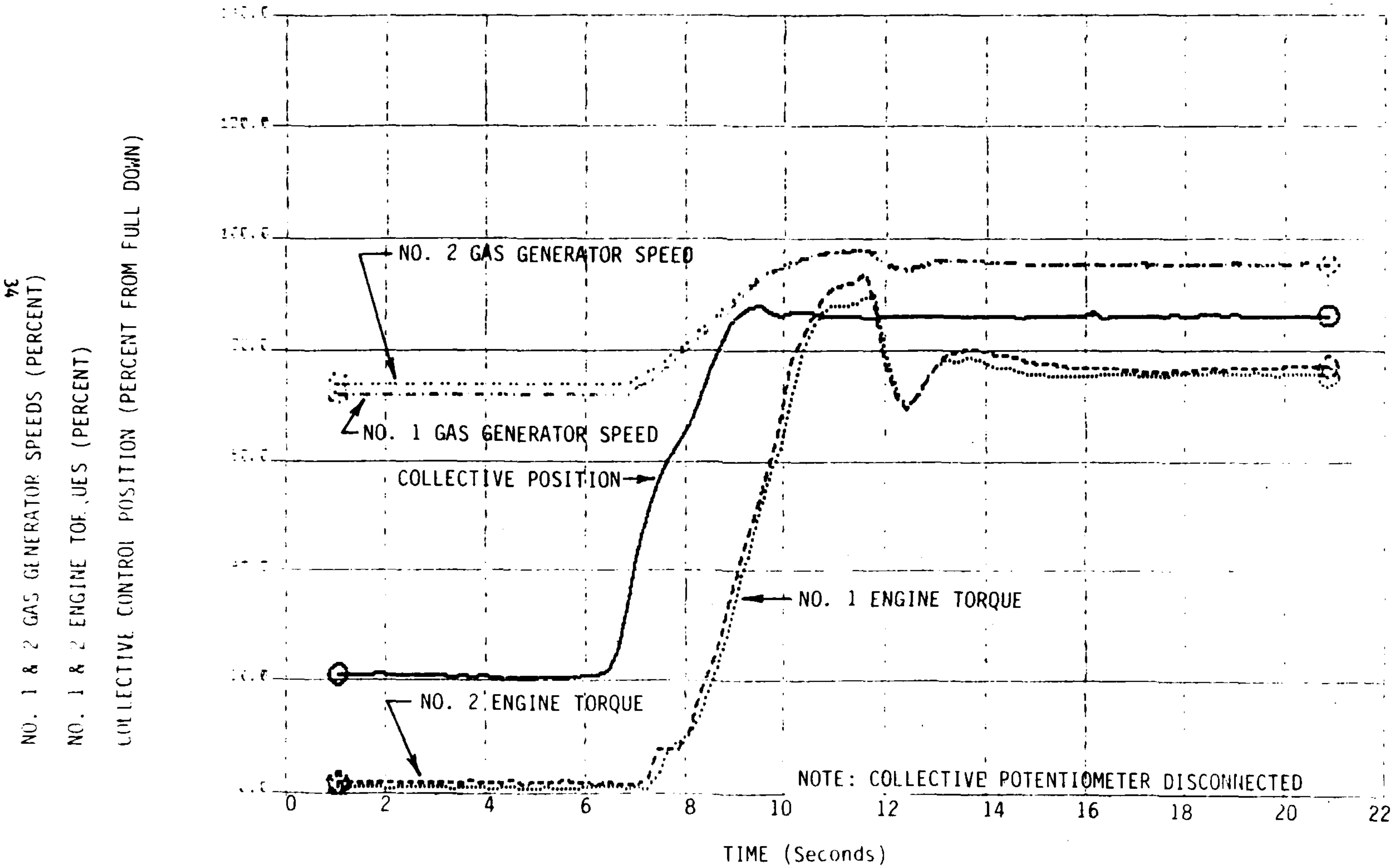


FIGURE 4C

RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

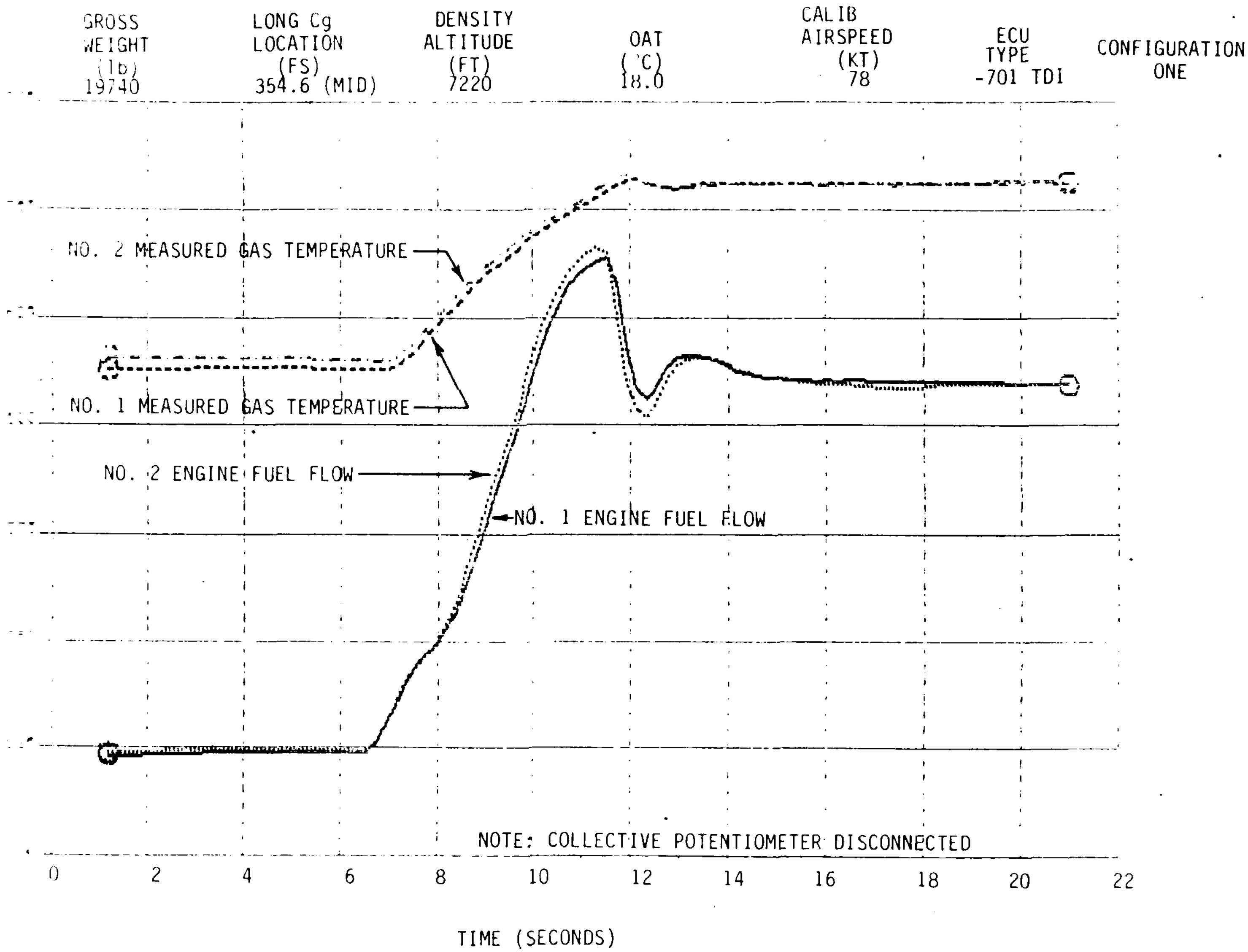


FIGURE 5A

QUICK STOP
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG. C)	ENTRY CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
17690	352.8 (MID)	2910	31.0	116	-701 TDI	ONE

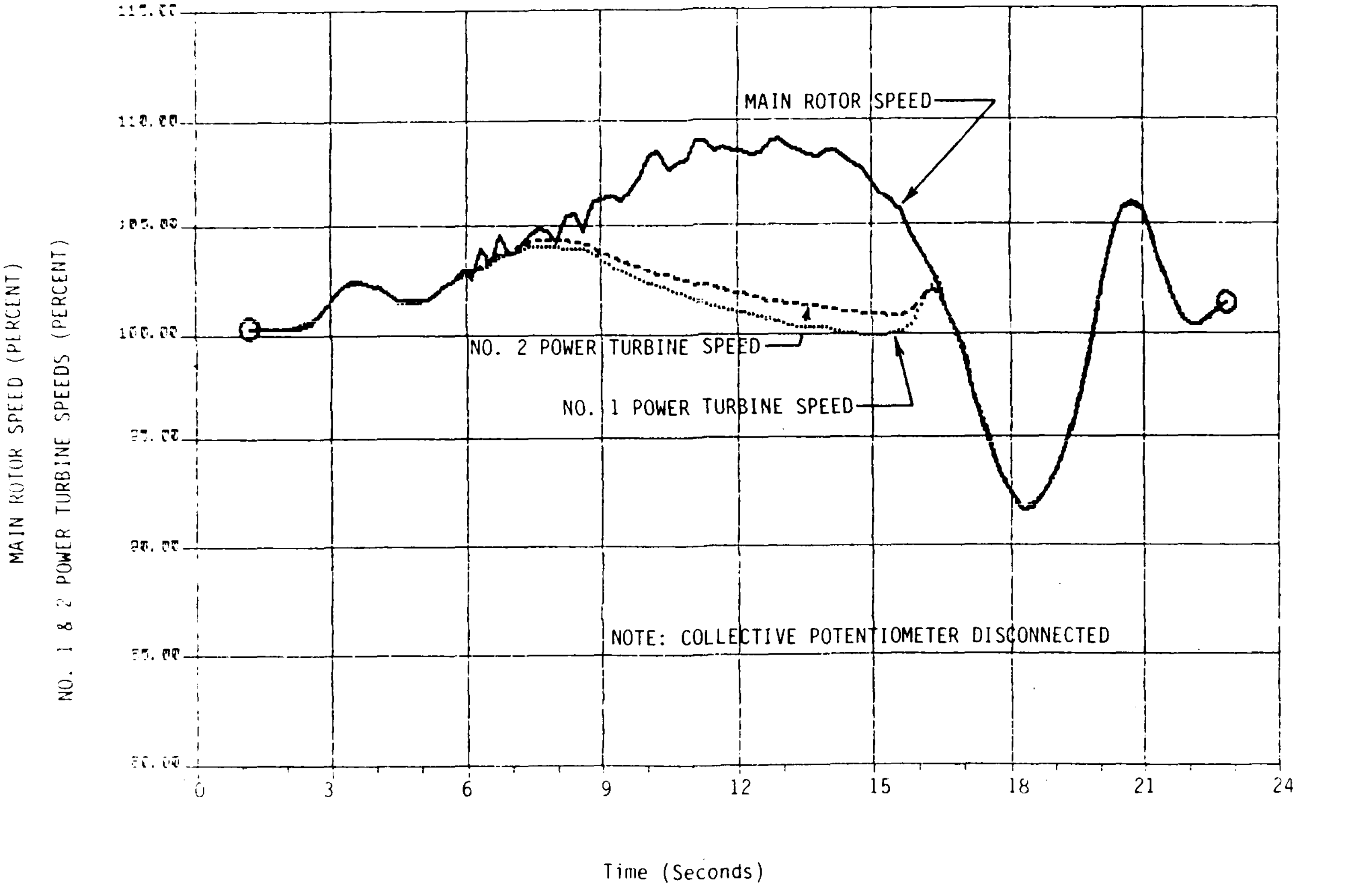


FIGURE 5B

QUICK STOP
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION ONE
17690	352.8(MID)	2910	31.0	116	-701 TYPE	

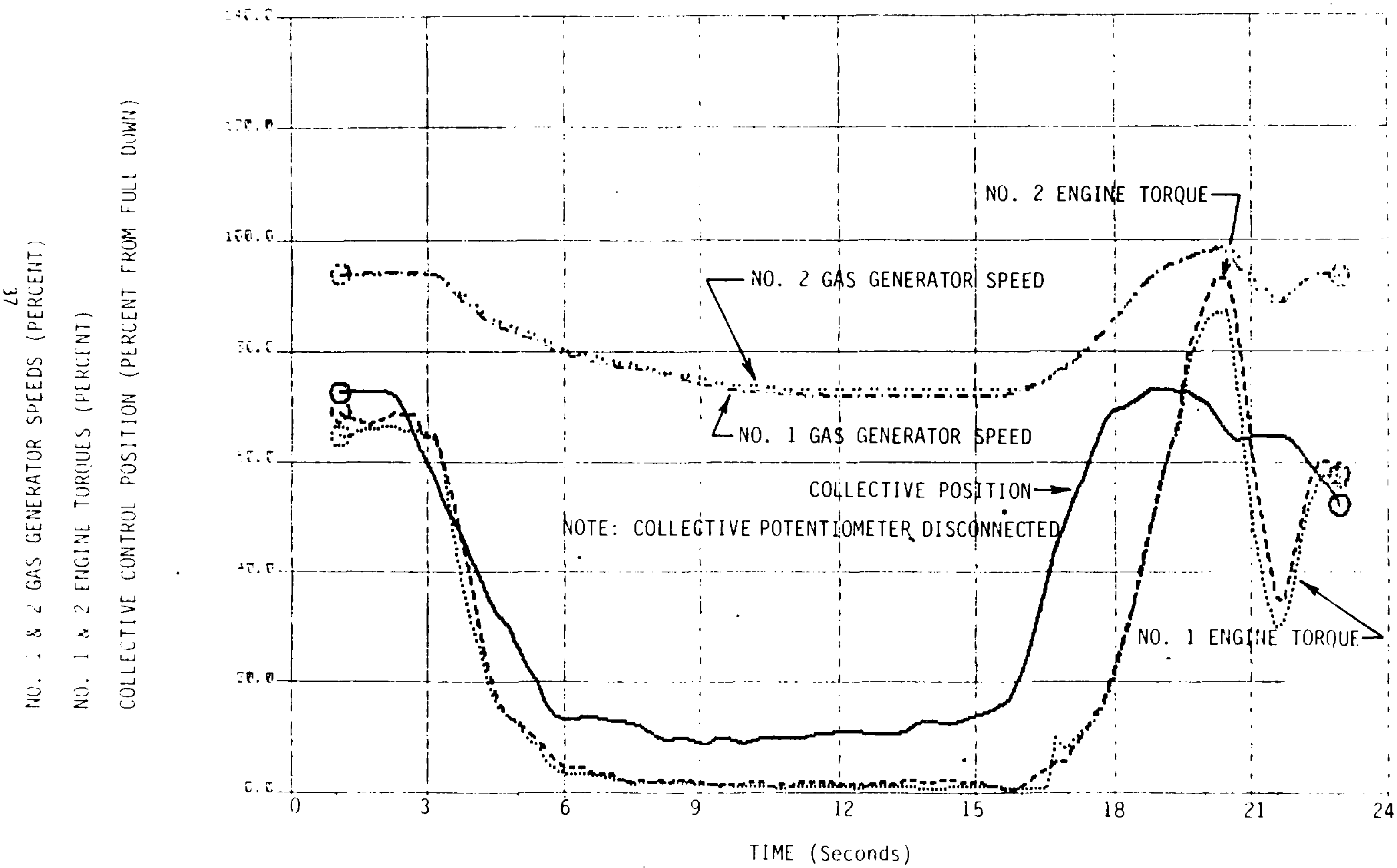


FIGURE 5C

QUICK STOP
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG. C)	ENTRY CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
17690	352.8 (MID)	2910	31.0	116	-701 TDI	ONE

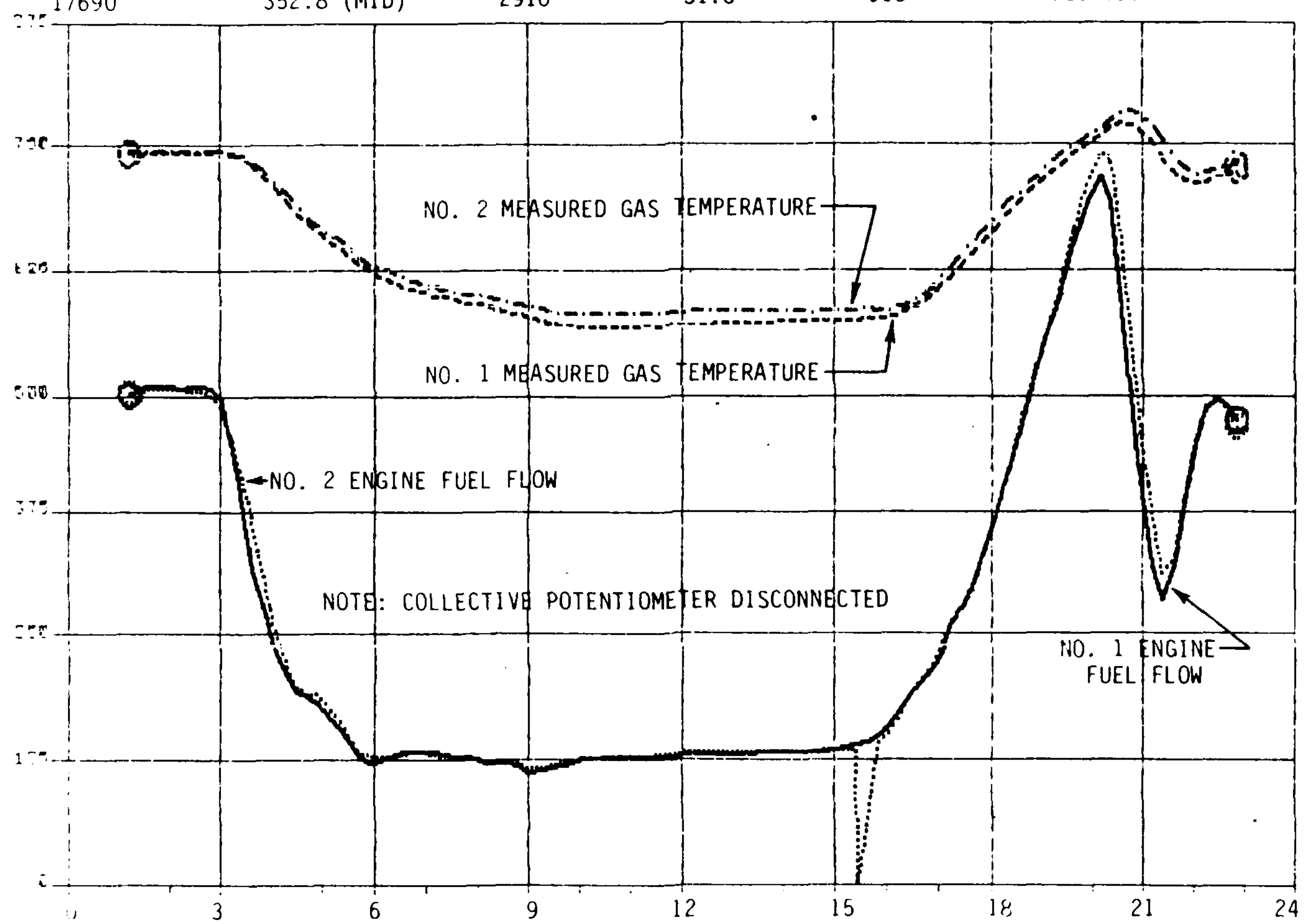


FIGURE 5D

QUICK STOP
HH-60A USAF S/N 82-23718

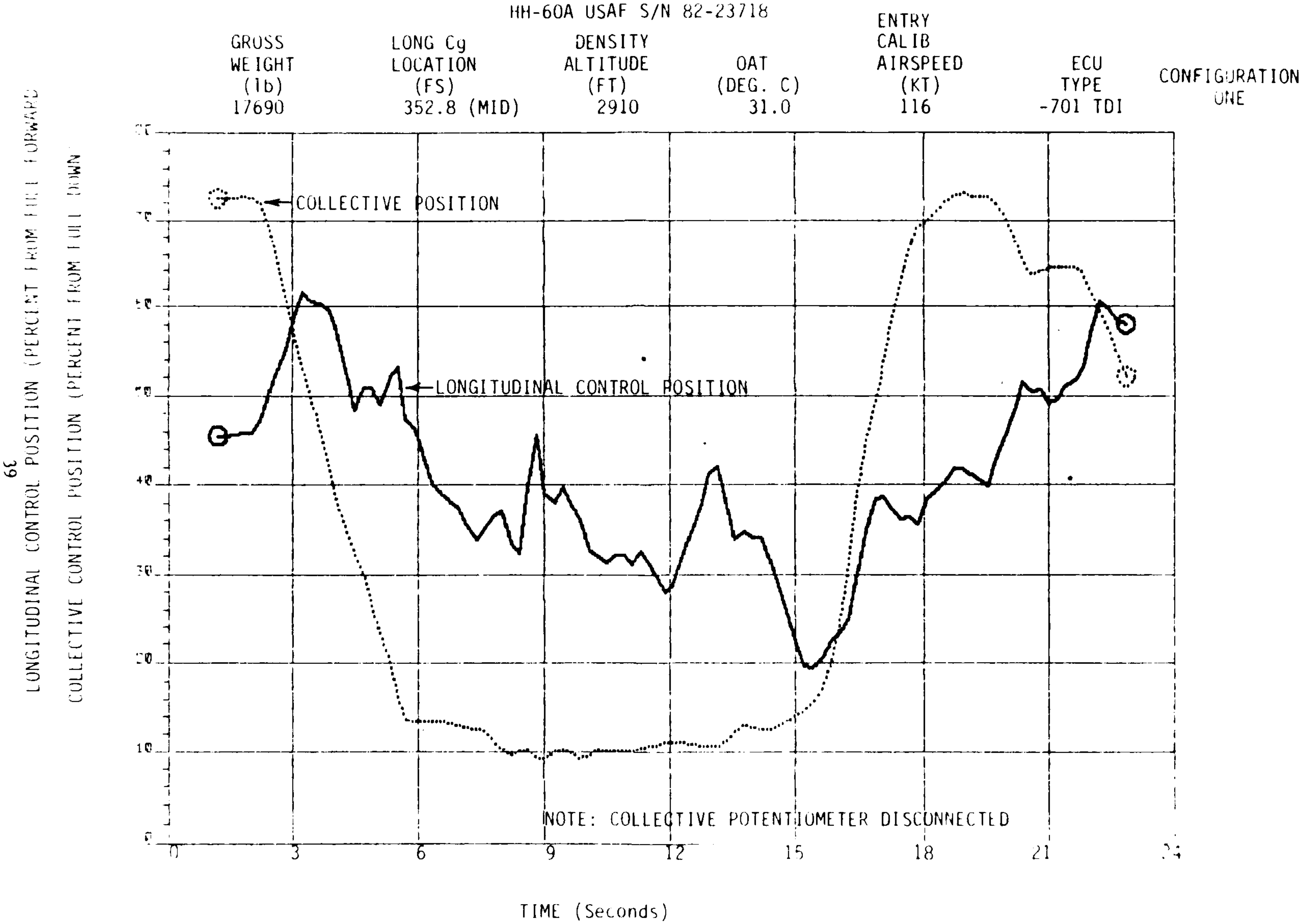


FIGURE 5E

QUICK STOP
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG. C)	ENTRY CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
17690	352.8 (MID)	2910	31.0	116	-701 TDI	ONE

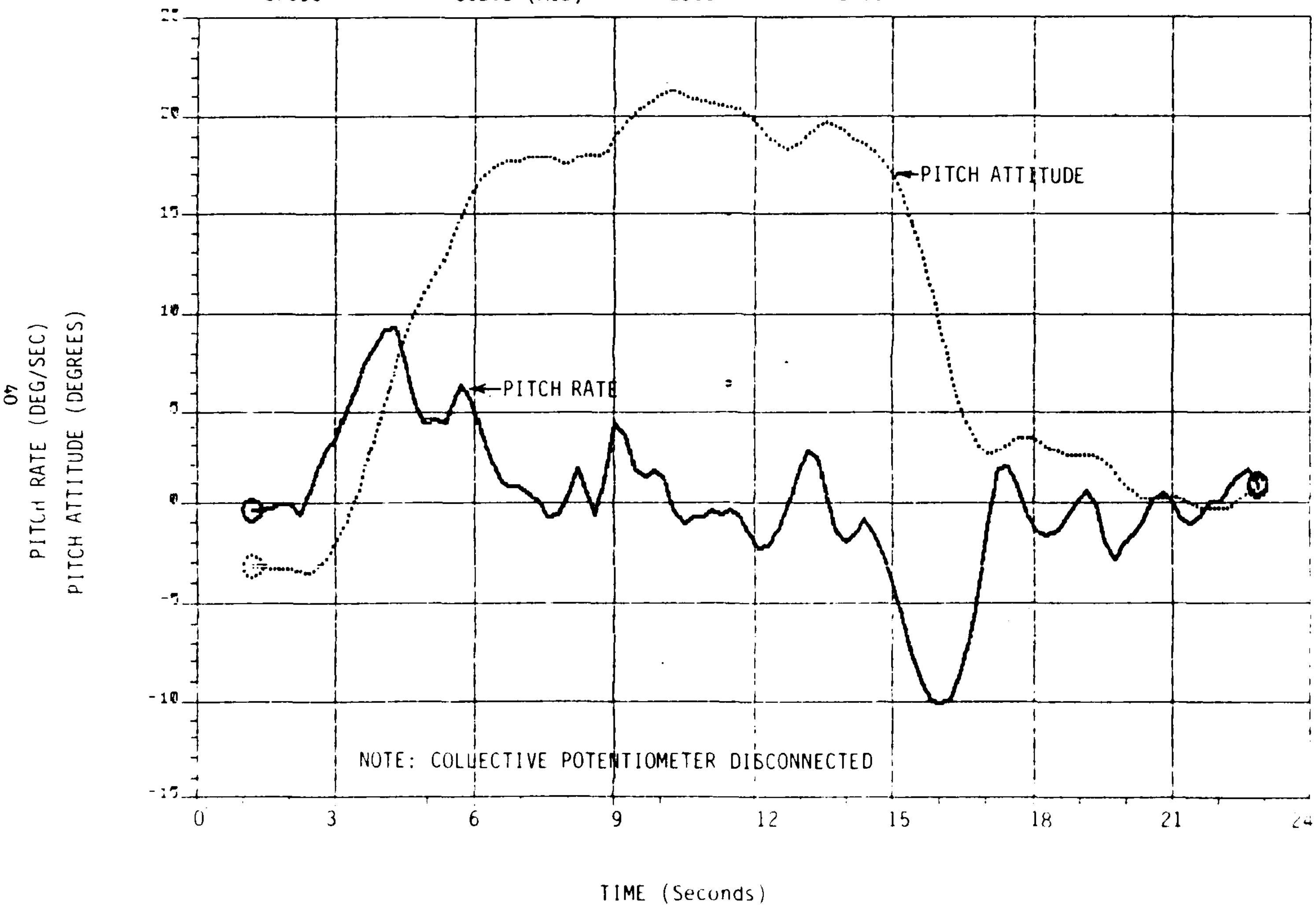


FIGURE 6A

JUMP TAKEOFF
HH-60A USAF S/N 83-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ECU TYPE	CONFIGURATION
19720	353.7 (MID)	2760	22.5	-701 TDI	TWO

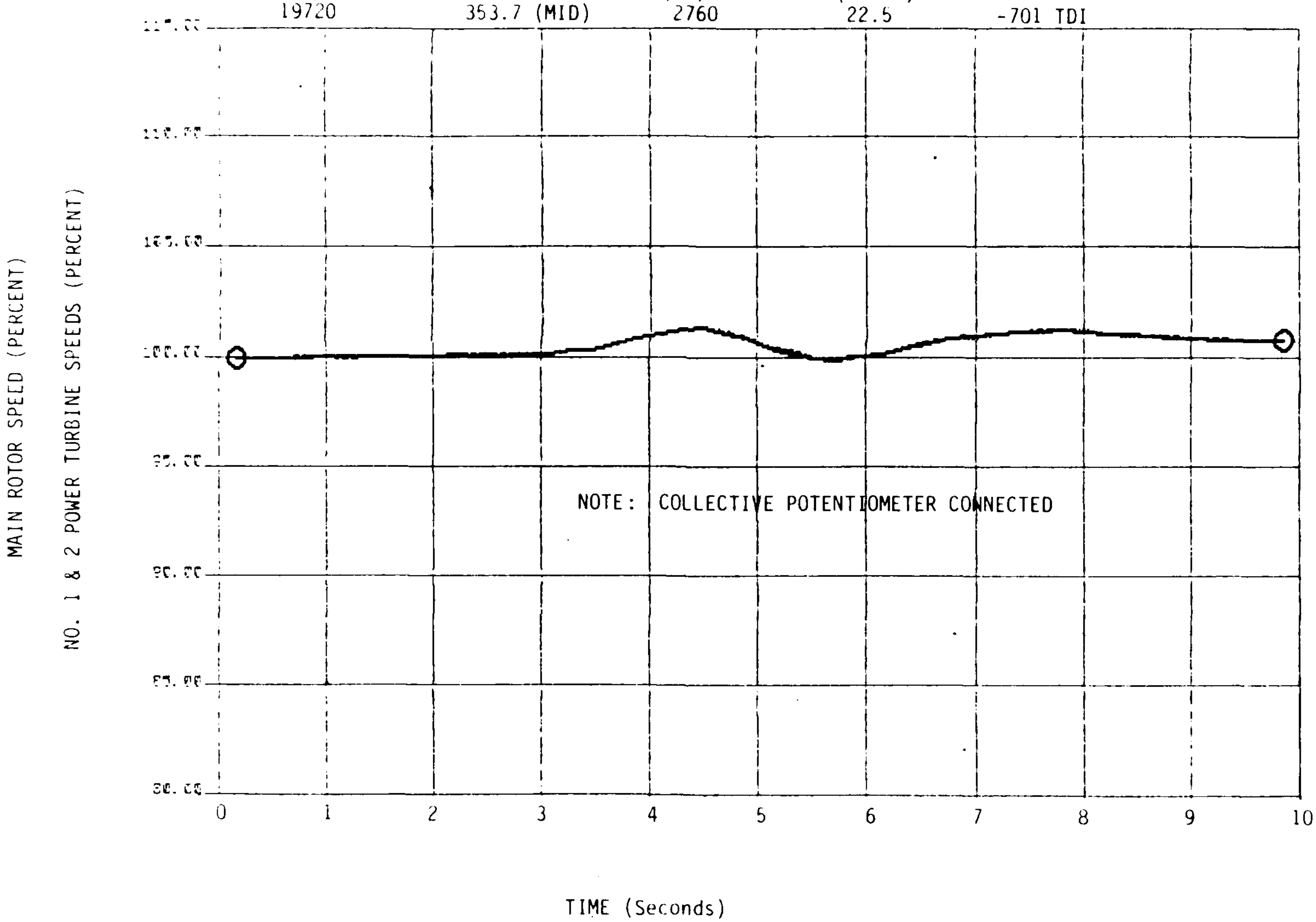


FIGURE 6B

JUMP TAKEOFF
HH-60A USAF S/N 83-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ECU TYPE	CONFIGURATION TWO
19720	353.7(MID)	2760	22.5	-701 TDI	

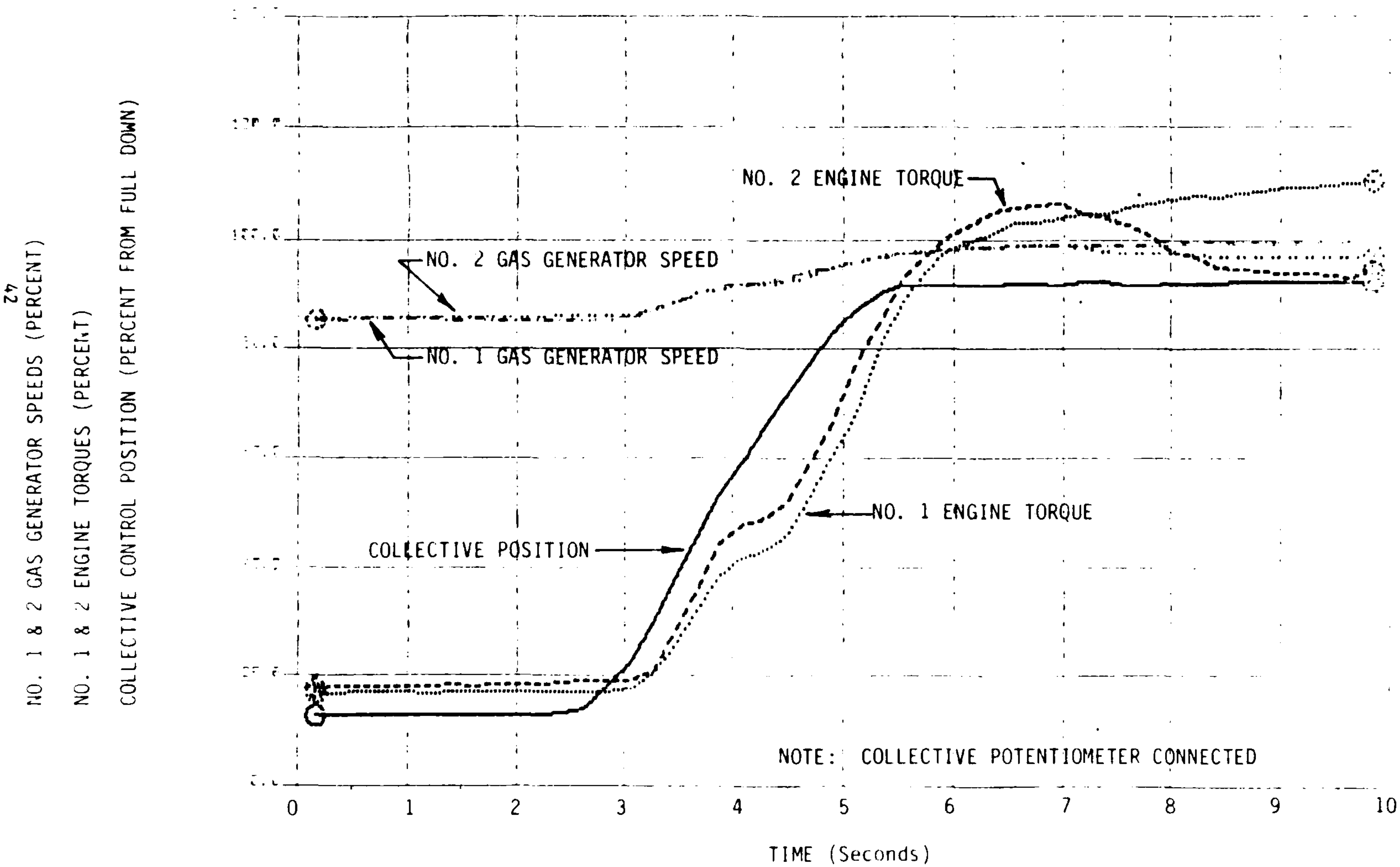


FIGURE 6C

JUMP TAKEOFF
HH-60A USAF S/N 83-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ECU TYPE	CONFIGURATION
19720	353.7 (MID)	2760	22.5	-701 TDI	TWO

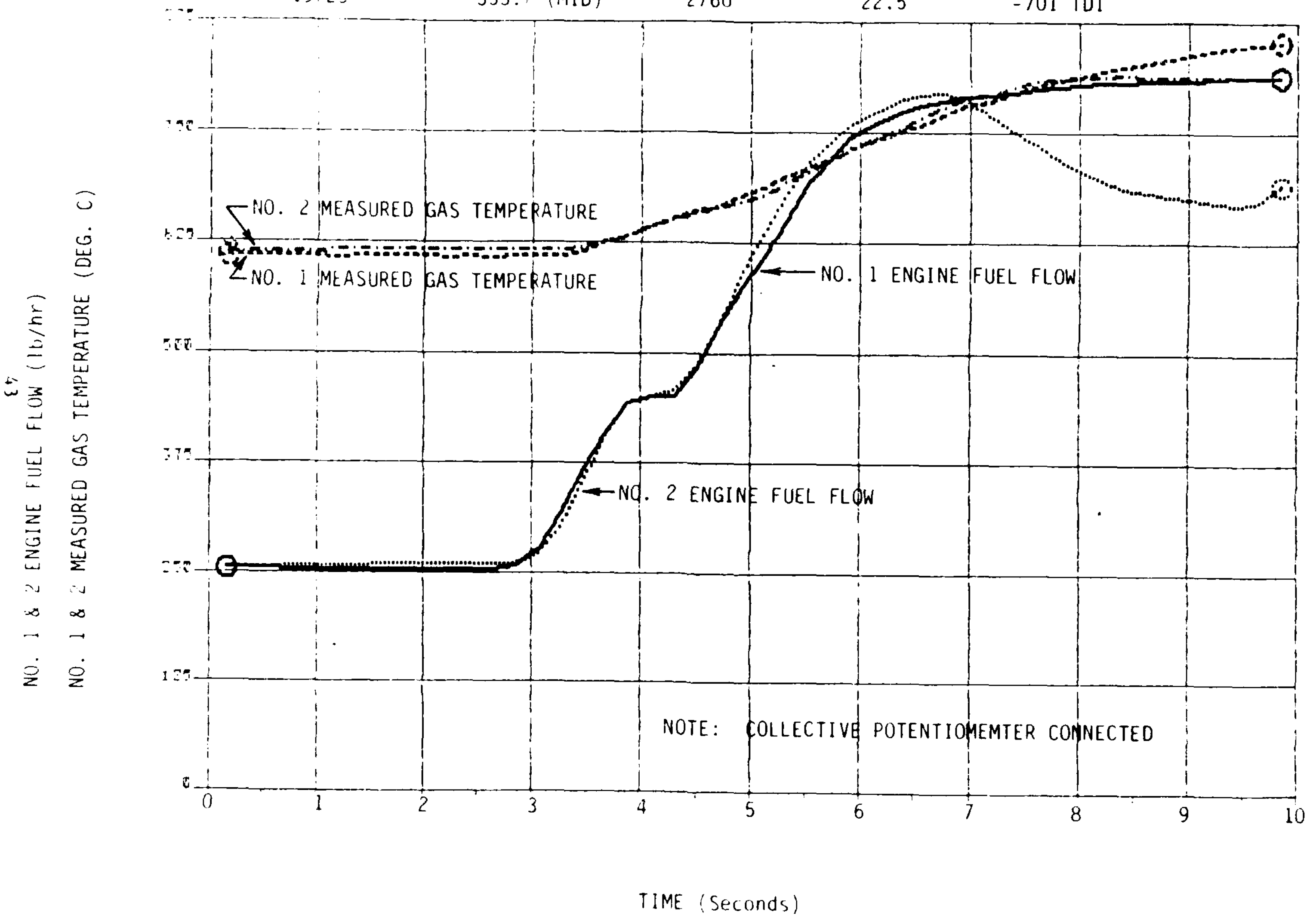


FIGURE 7A

RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

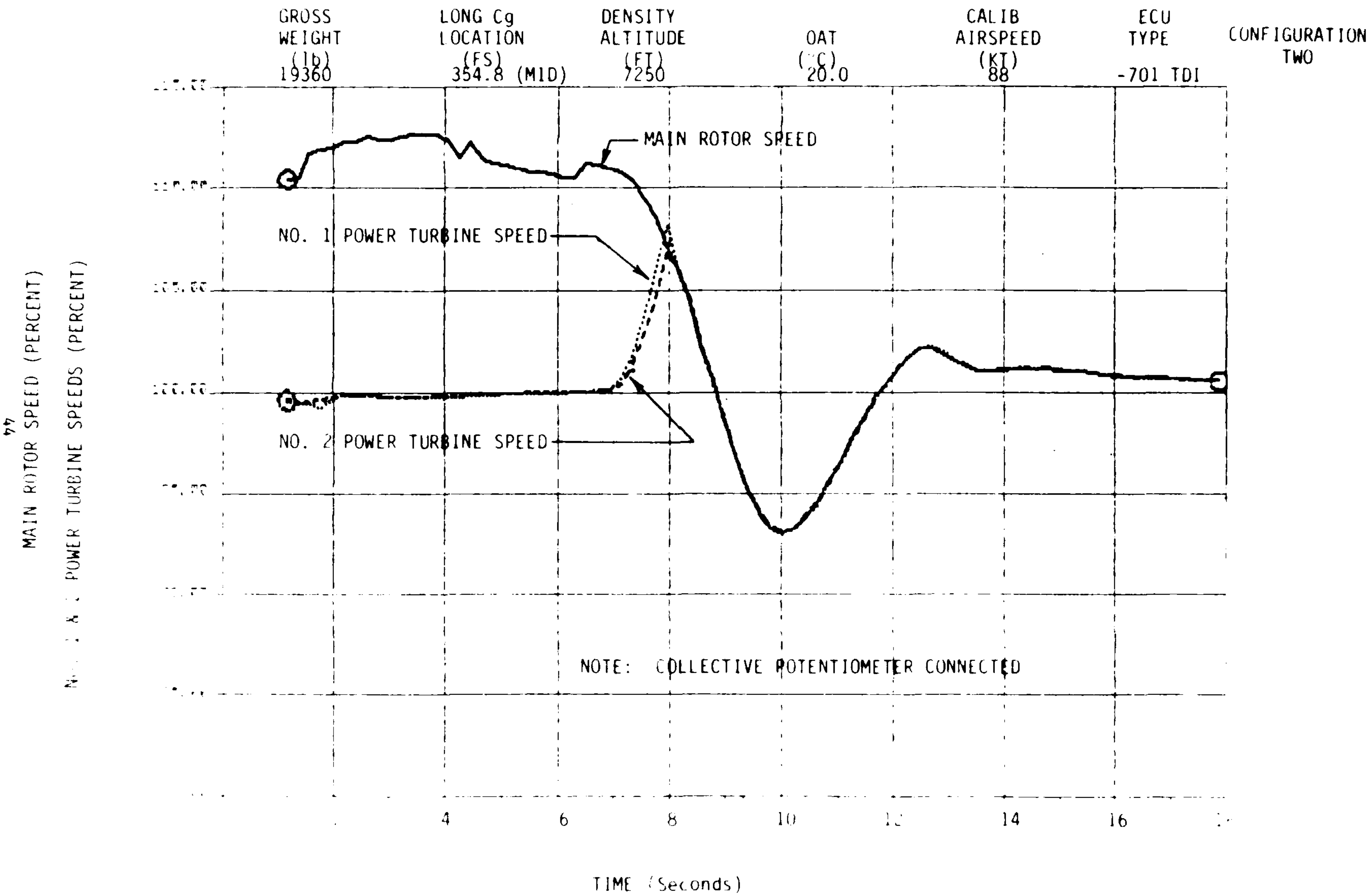


FIGURE 7B

RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

GROSS WEIGHT (LB)	LONG CG LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION TWO
19360	354.8(MID)	7250	20.0	88	-701 TDI	

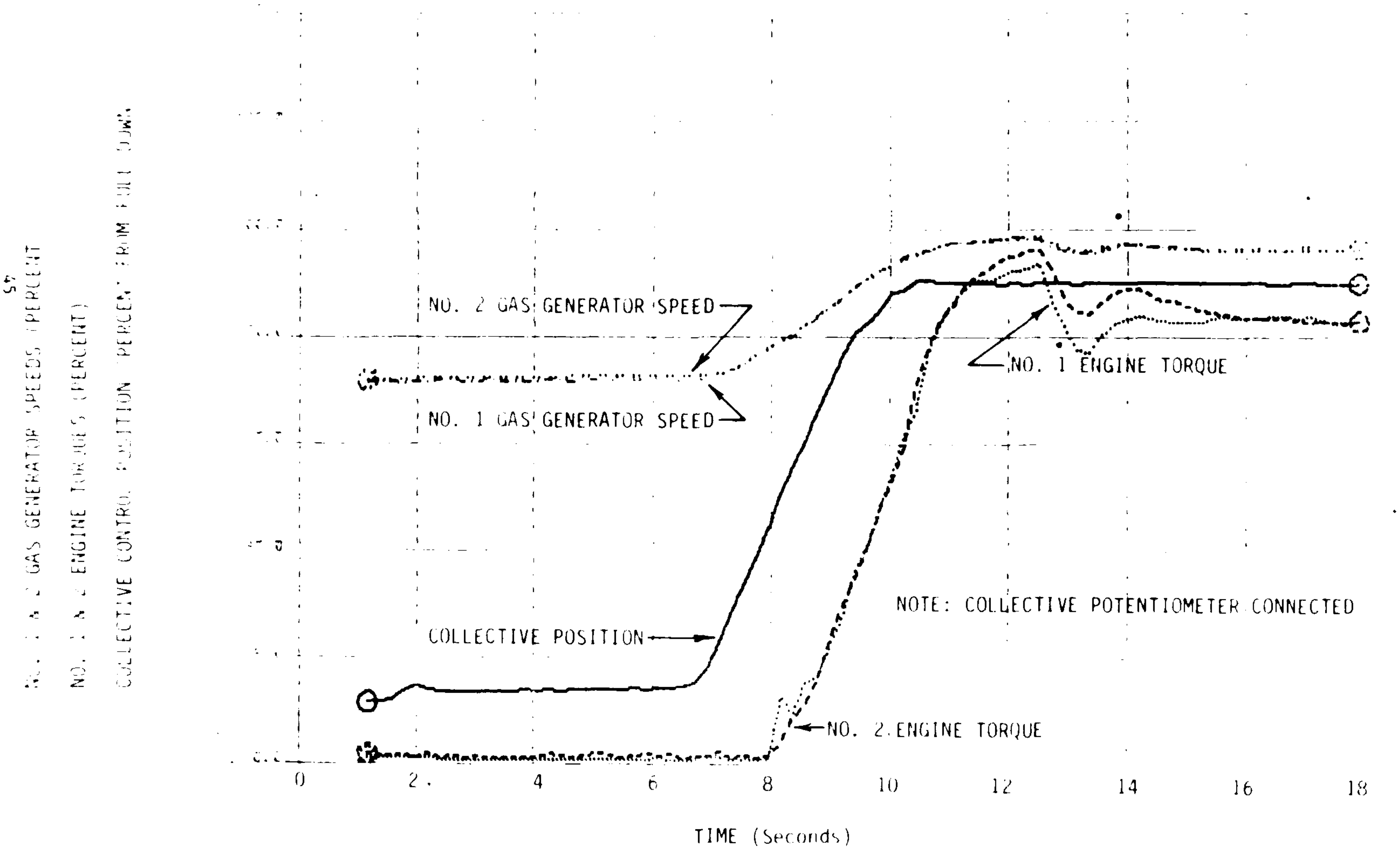


FIGURE 7C

RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
19360	354.8 (MID)	7250	20.0	88	-701 TDI	TWO

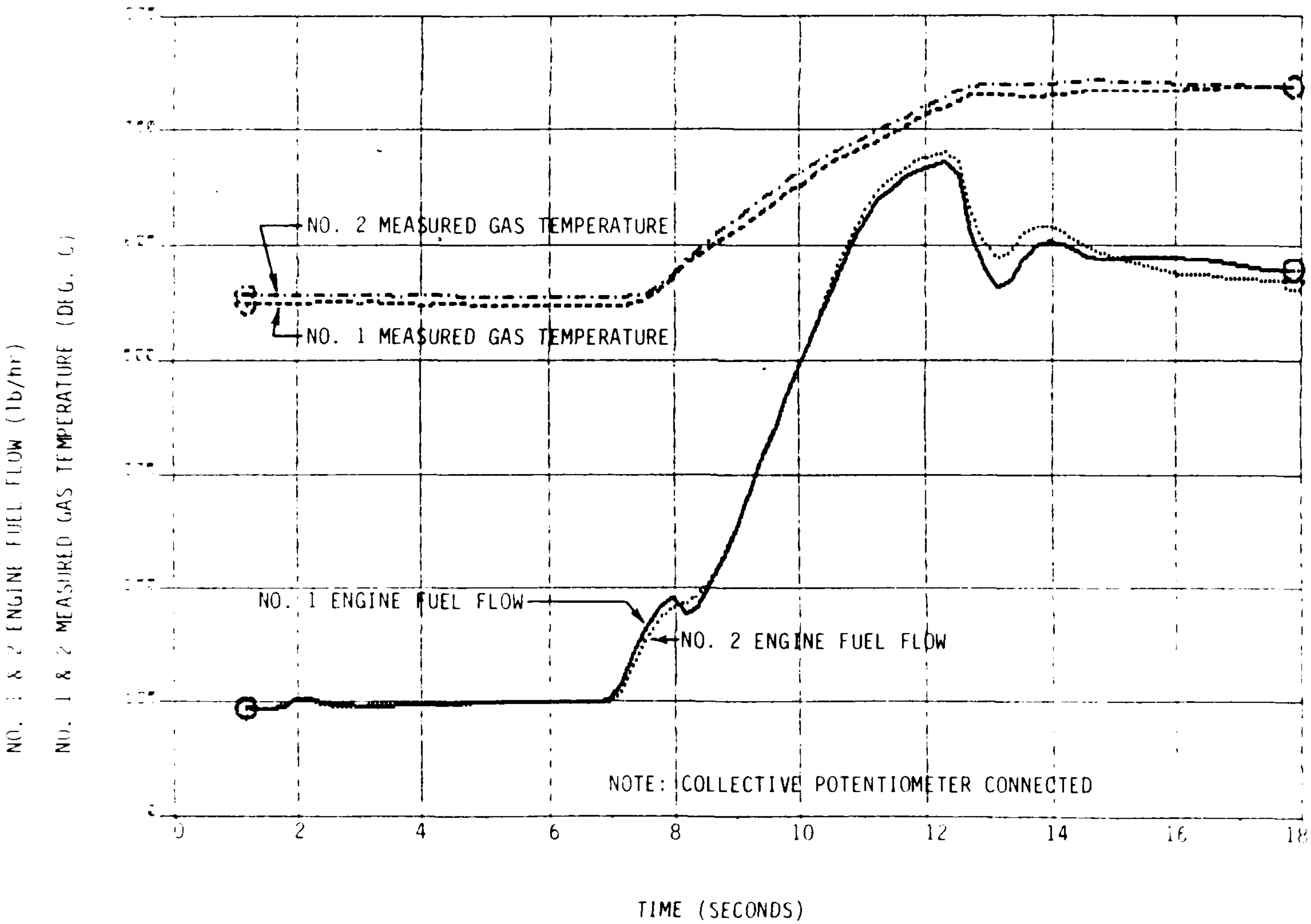


FIGURE 8A

RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
19510	354.0 (MID)	6910	20.5	85	-701 (TDI	TWO

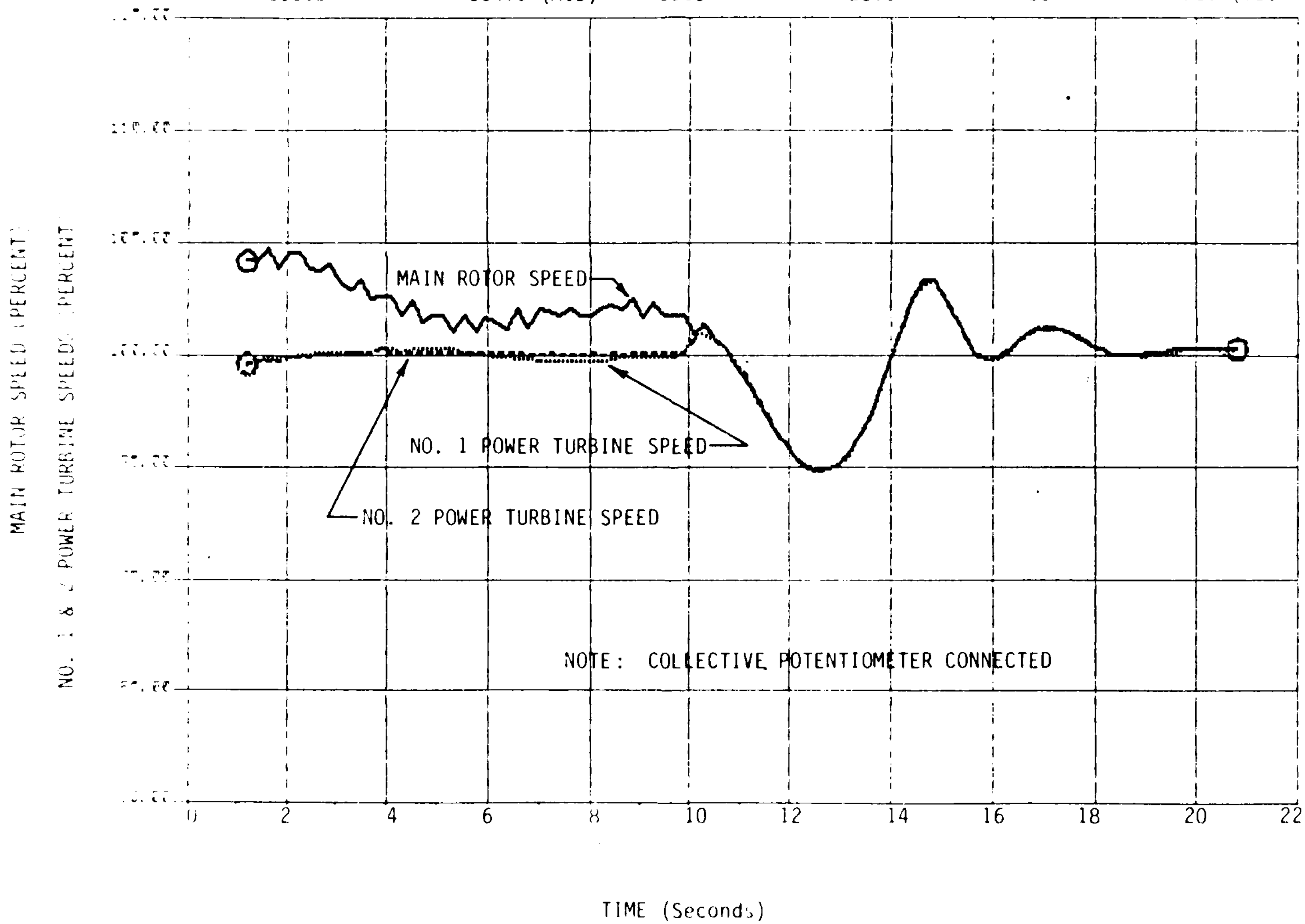


FIGURE 8B

RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	CALB AIRSPEED (KT)	ECU TYPE	CONFIGURATION TWO
19510	354.0(MID)	6910	20.5	85	-701 TDI	

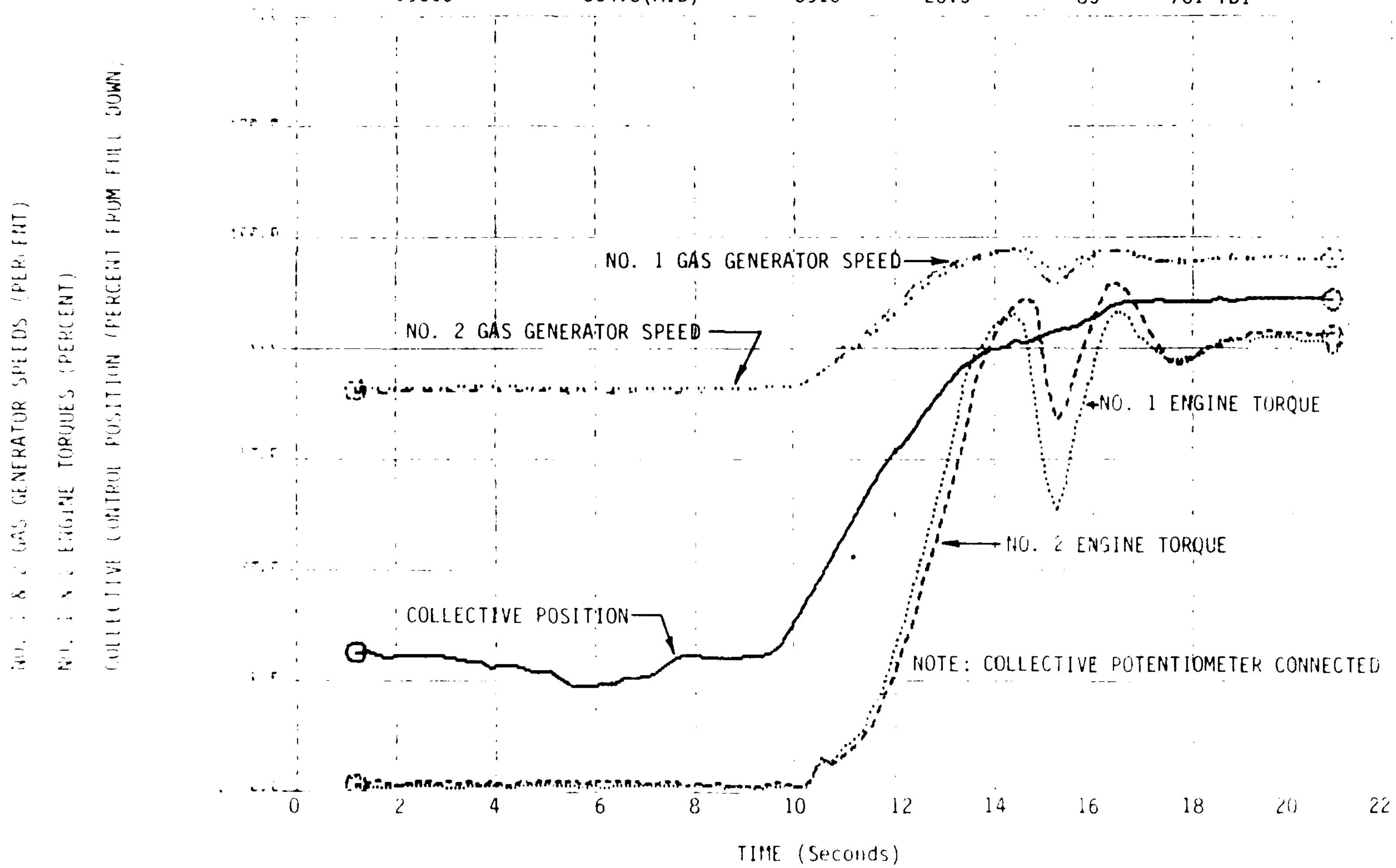


FIGURE 8C

RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

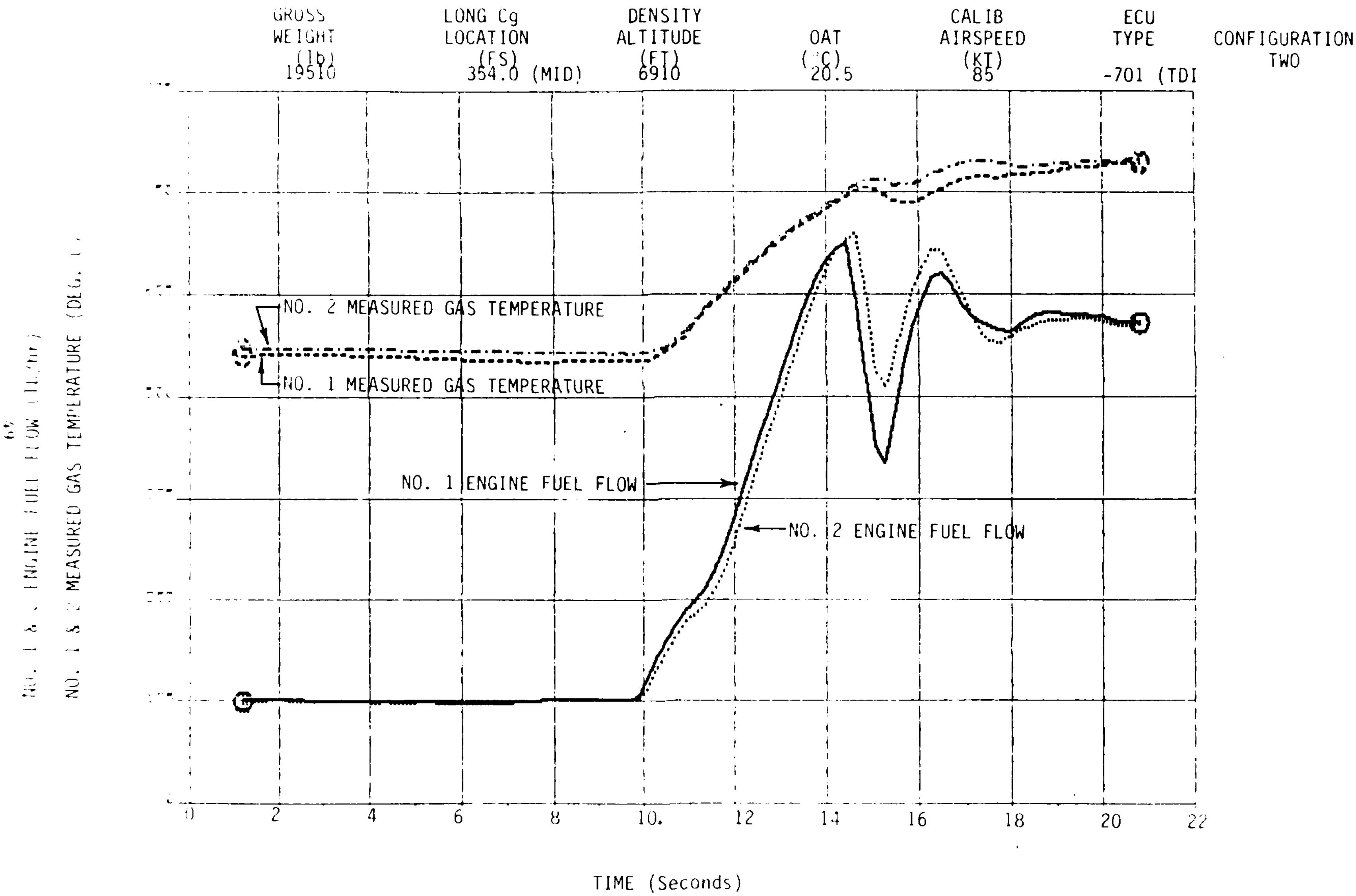


FIGURE 9A

QUICK STOP
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
18575	355.1 (MID)	2870	27.5	102	·701 TDI	TWO

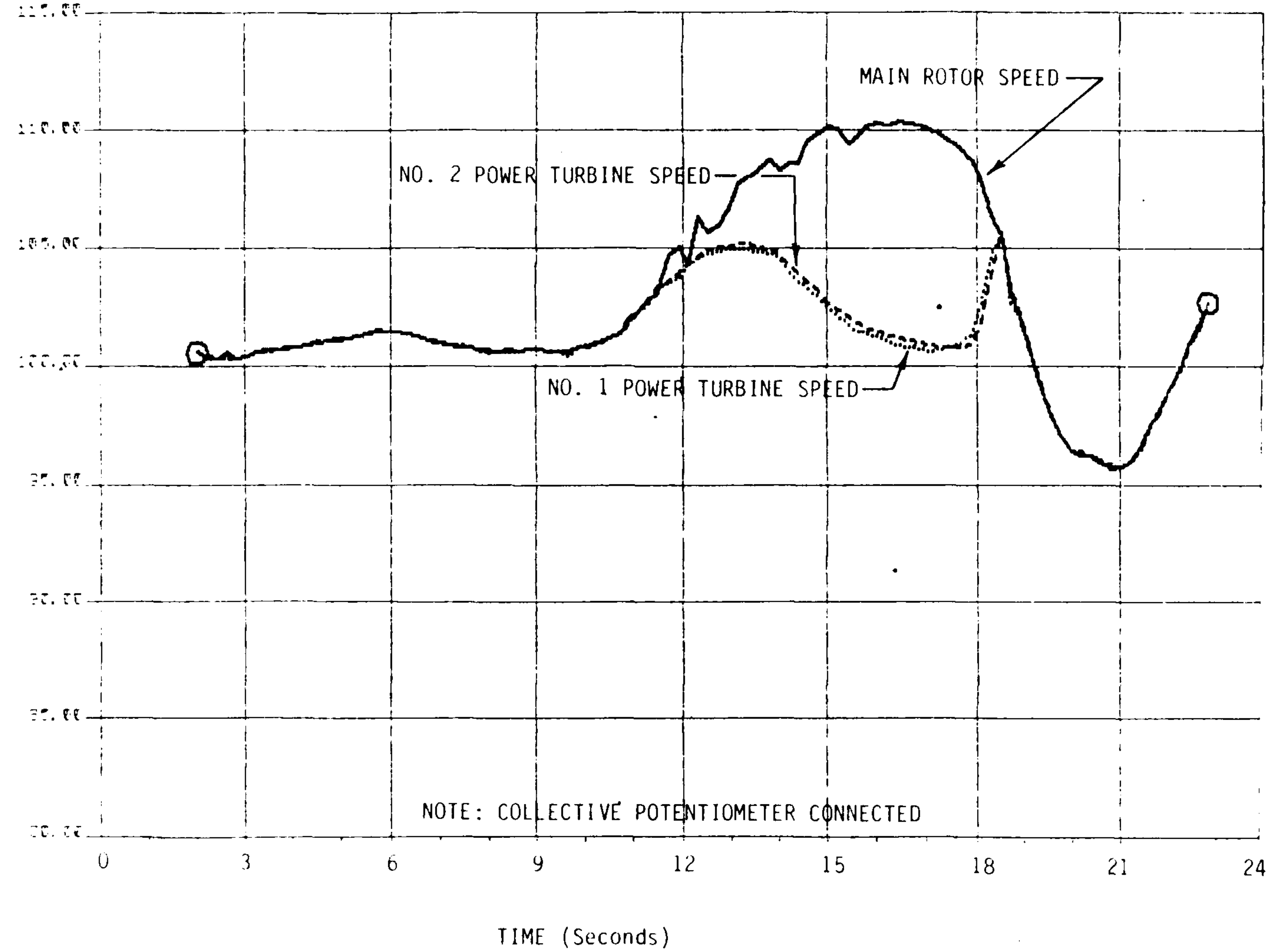


FIGURE 9B

QUICK STOP
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION TWO
18575	355.1(MID)	2870	27.5	102	-701 TDI	

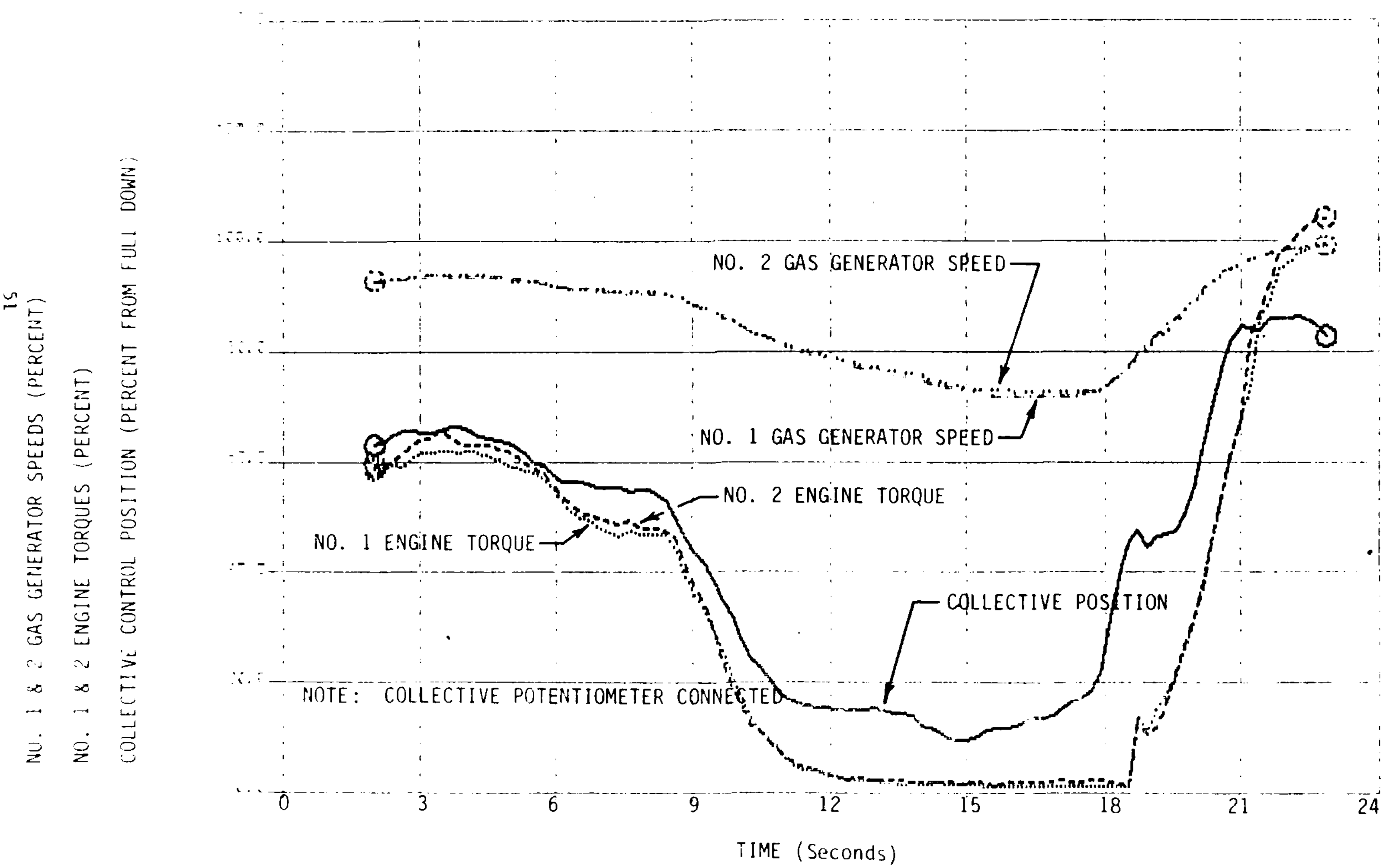


FIGURE 9C

QUICK STOP
HH-60A USAF S/N 82-23718

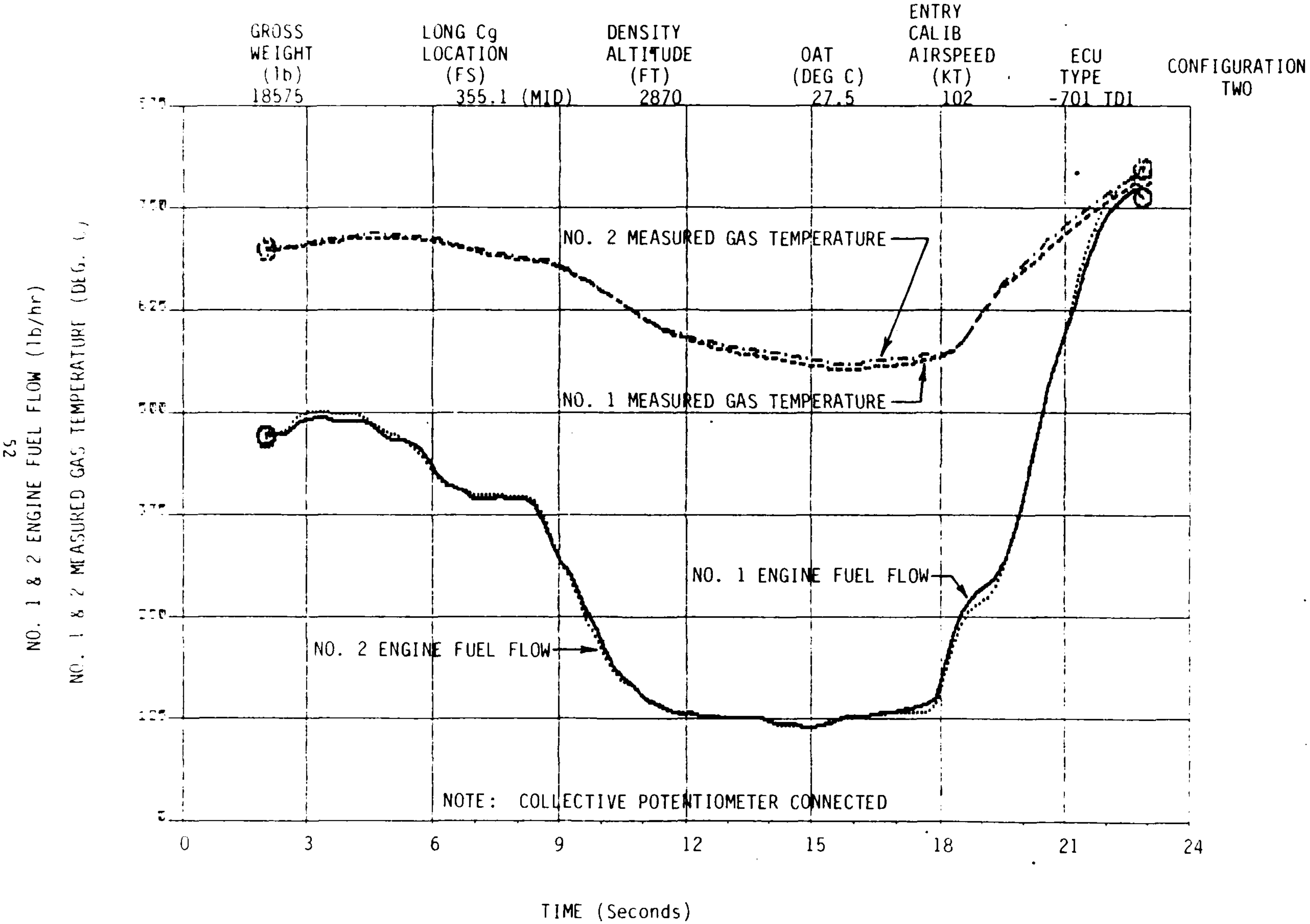


FIGURE 9D

QUICK STOP
HH-60A USAF S/N 82-23718

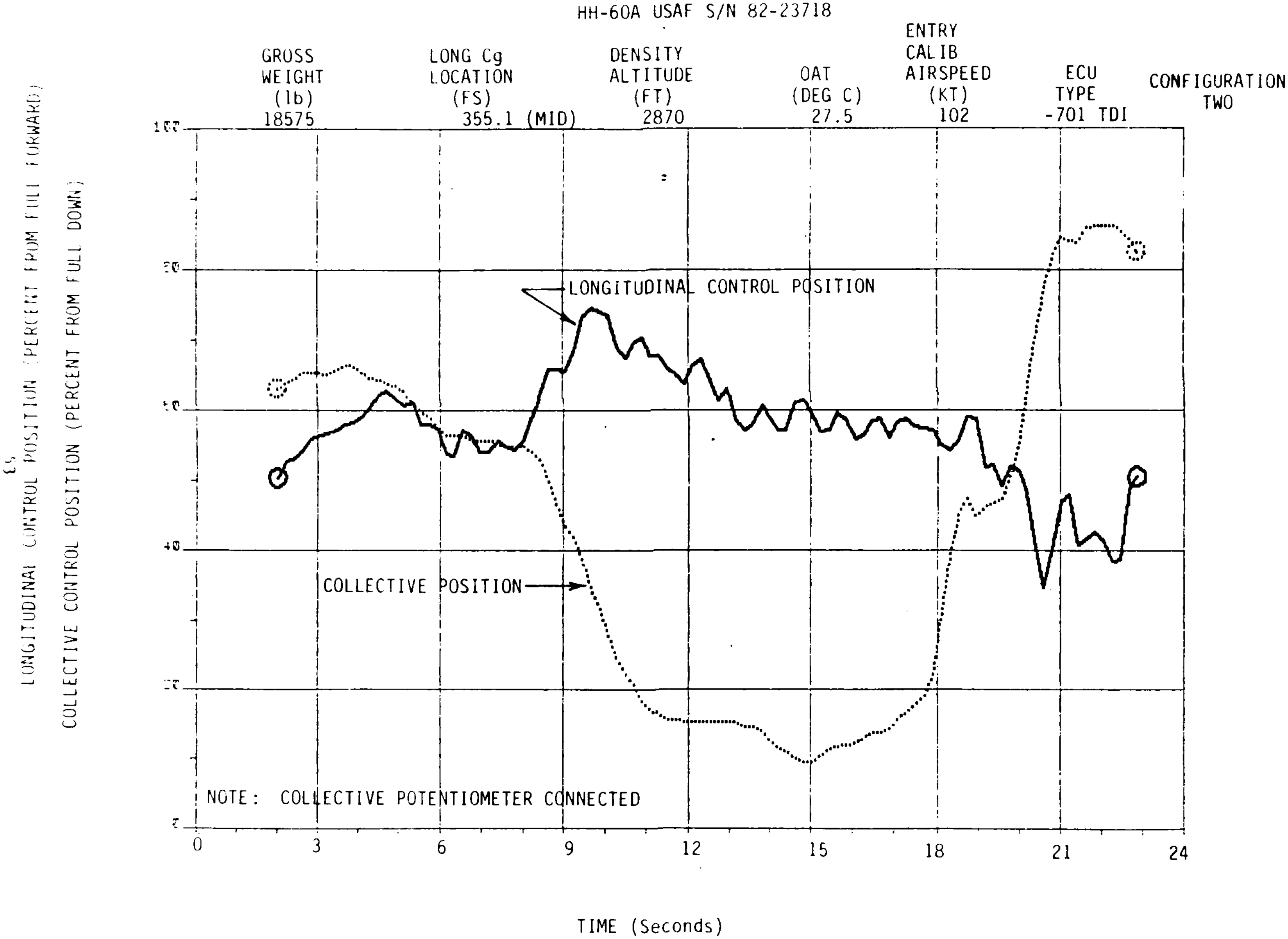


FIGURE 9E

QUICK STOP
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG. C)	ENTRY CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
18575	355.1 (MID)	2870	27.5	102	-701 TDI	TWO

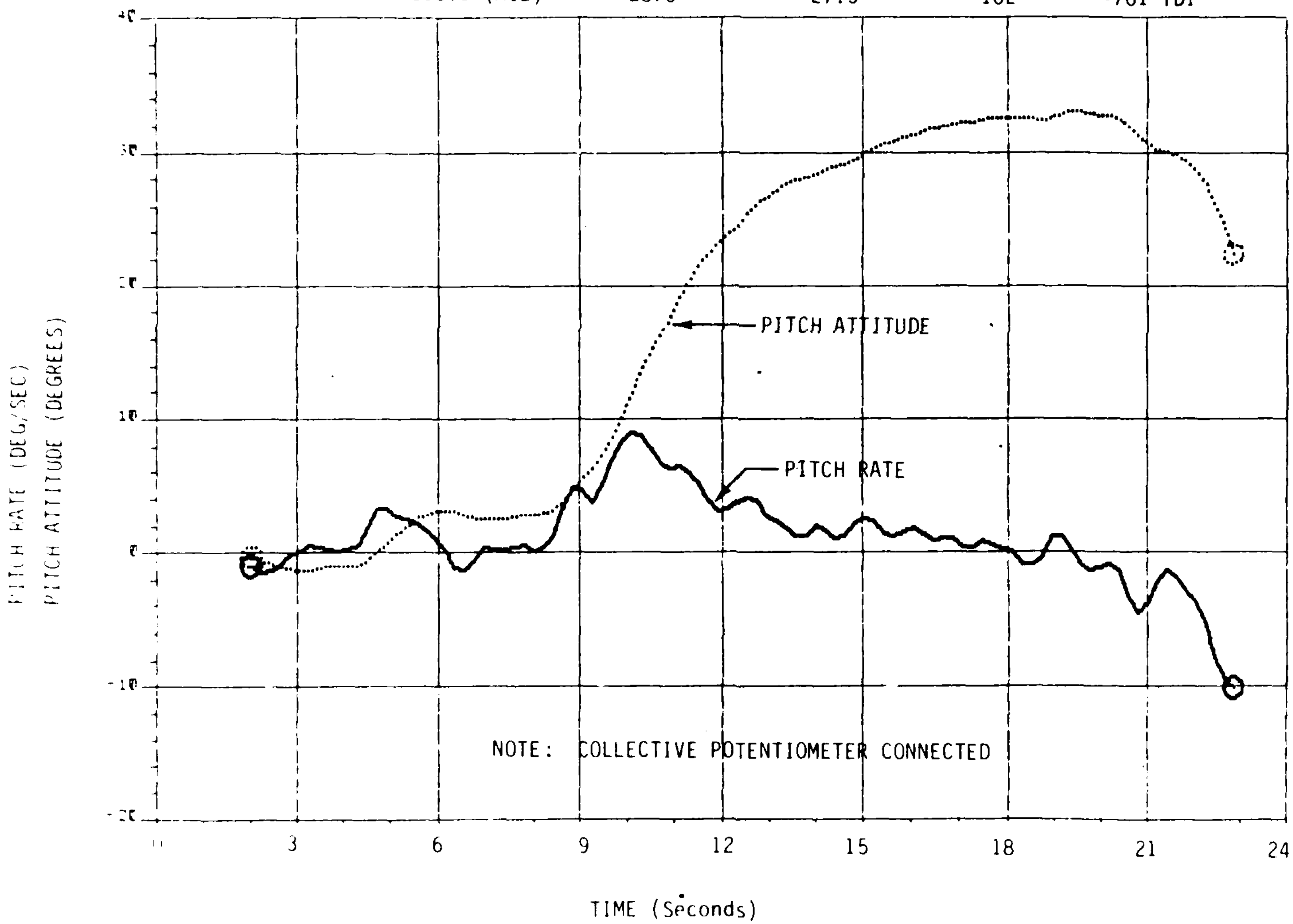


FIGURE 10A

QUICK STOP
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
19120	354.8 (MID)	2880	24.5	59	-701 TDI	TWO

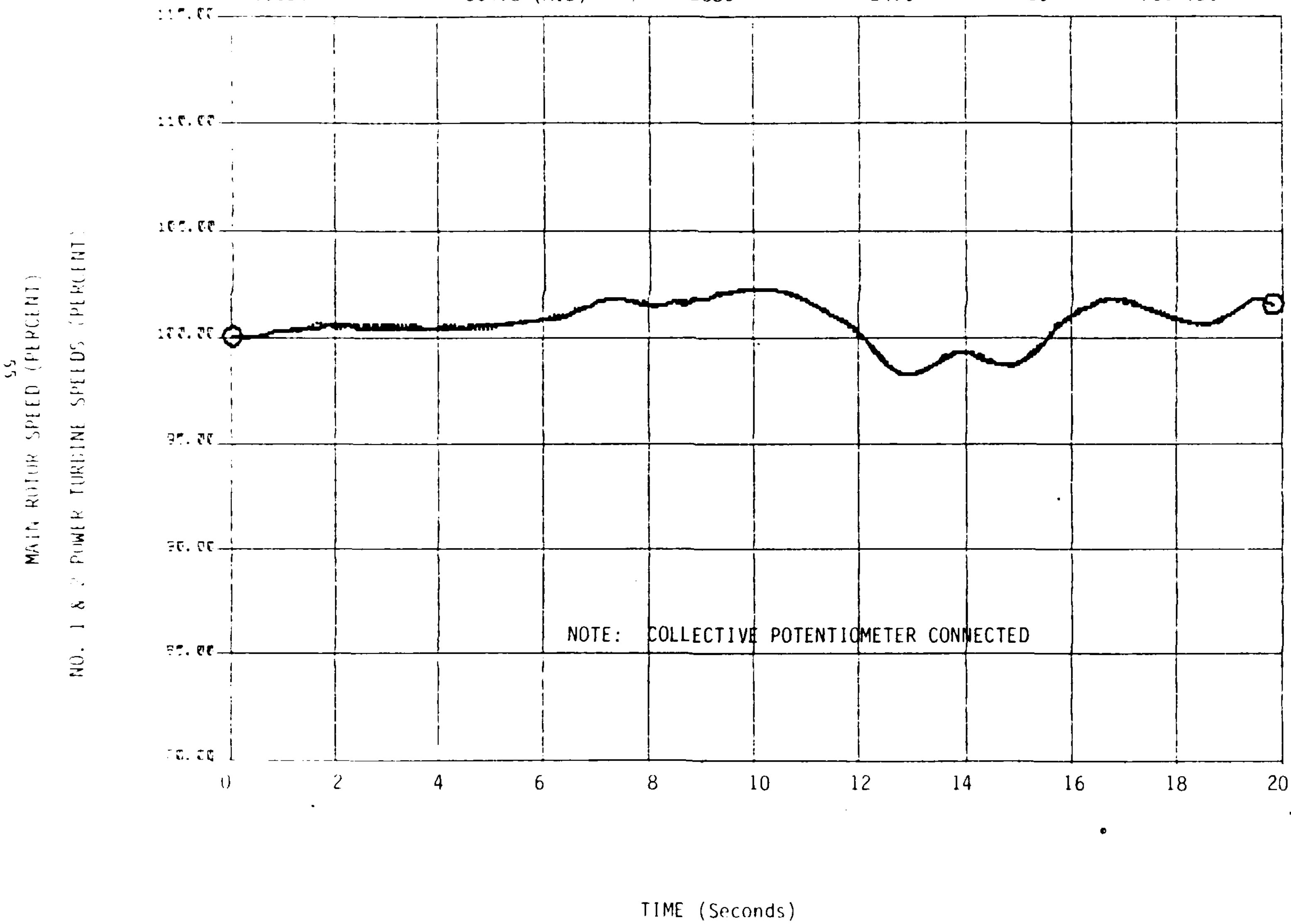


FIGURE 10B

QUICK STOP
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION TWO
19120	354.8(MID)	2880	24.5	59	-701 TDI	

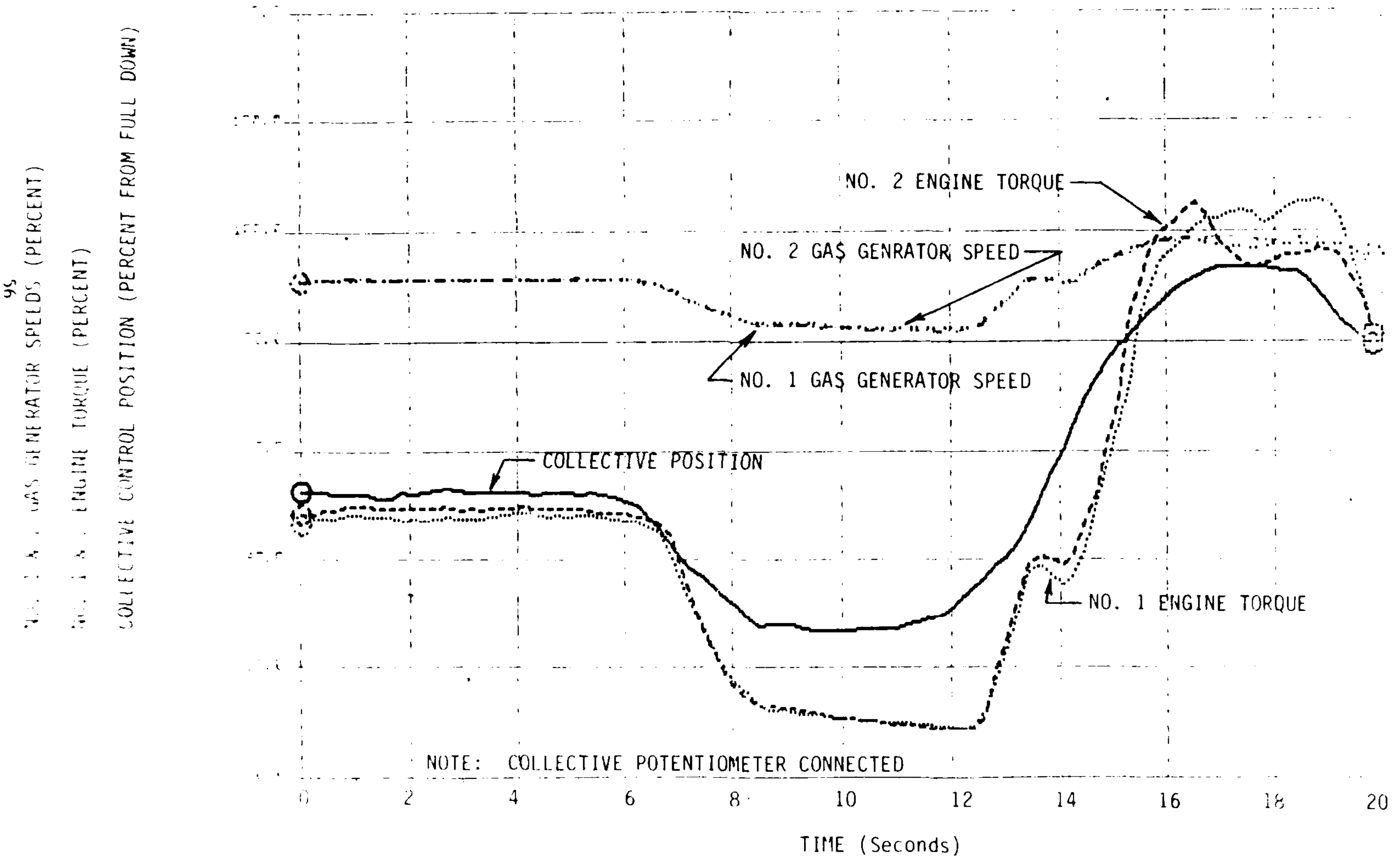


FIGURE 10C

QUICK STOP
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
19120	354.8 (MID)	2880	24.5	59	-701 TDI	TWO

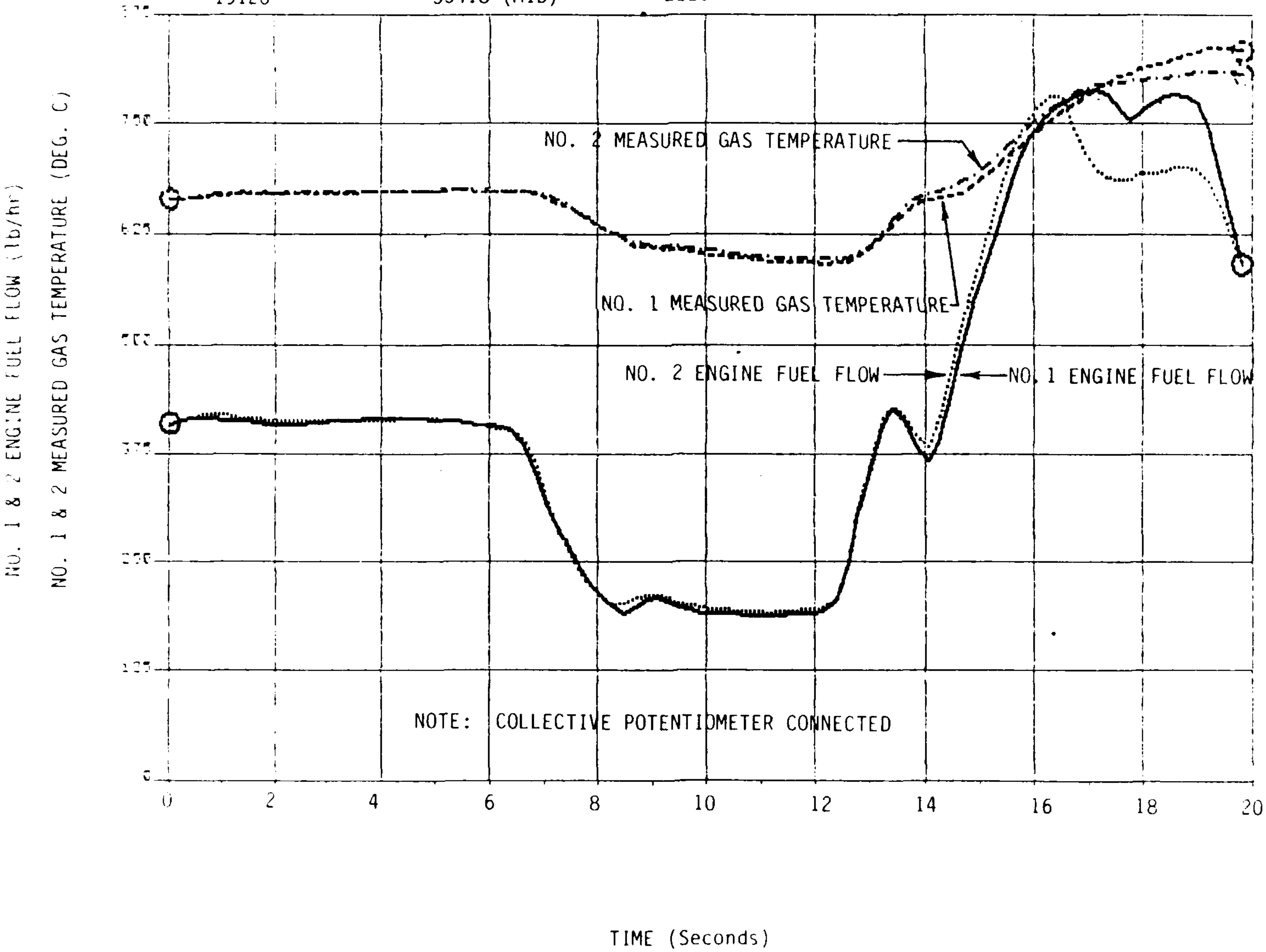


FIGURE 10D

QUICK STOP
HH-60A USAF S/N 82-23718

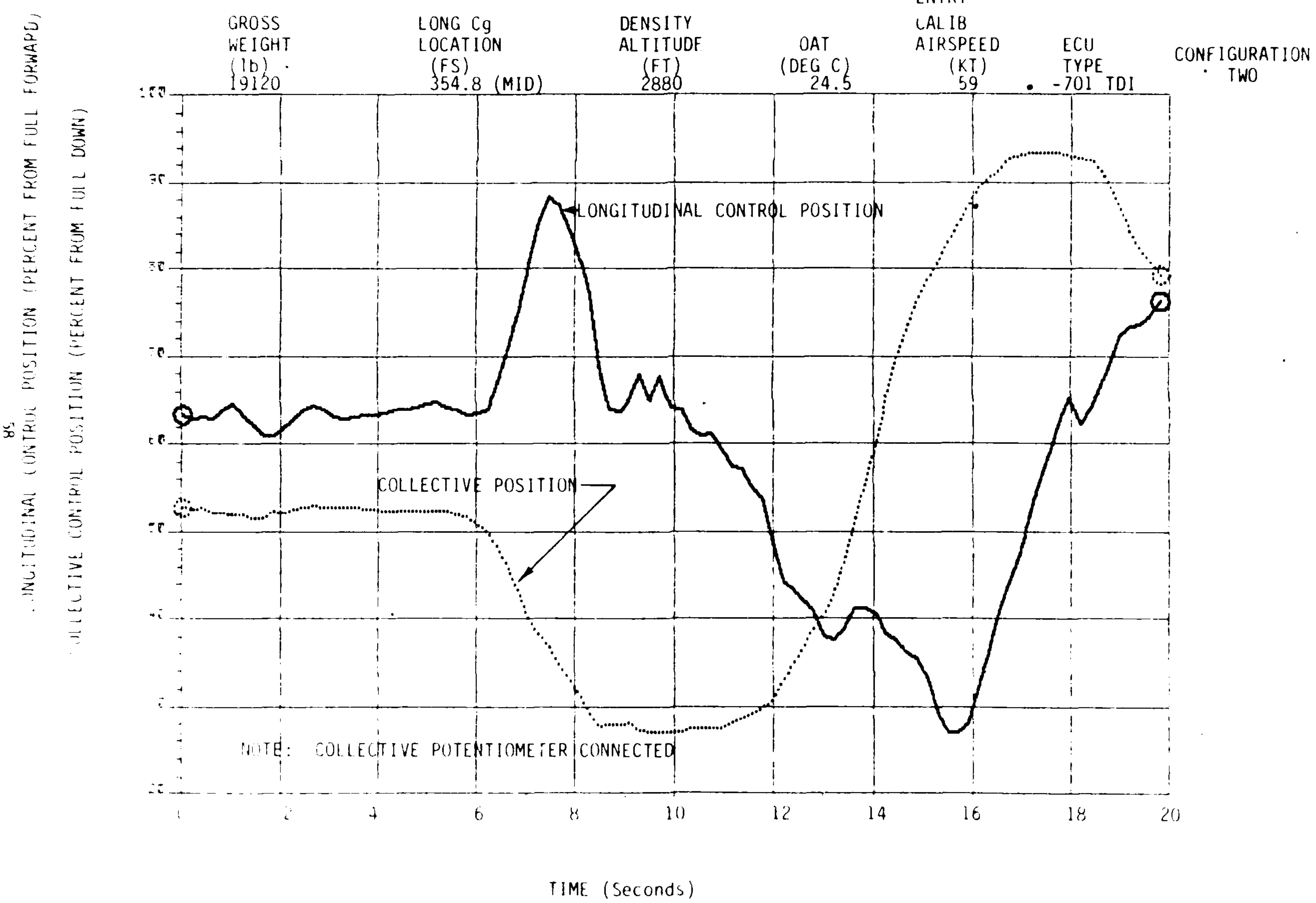


FIGURE 10E

QUICK STOP
HH-60A USAF S/N 82-23718

LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
354.8 (MID)	2880	24.5	59	-701 TDI	TWO

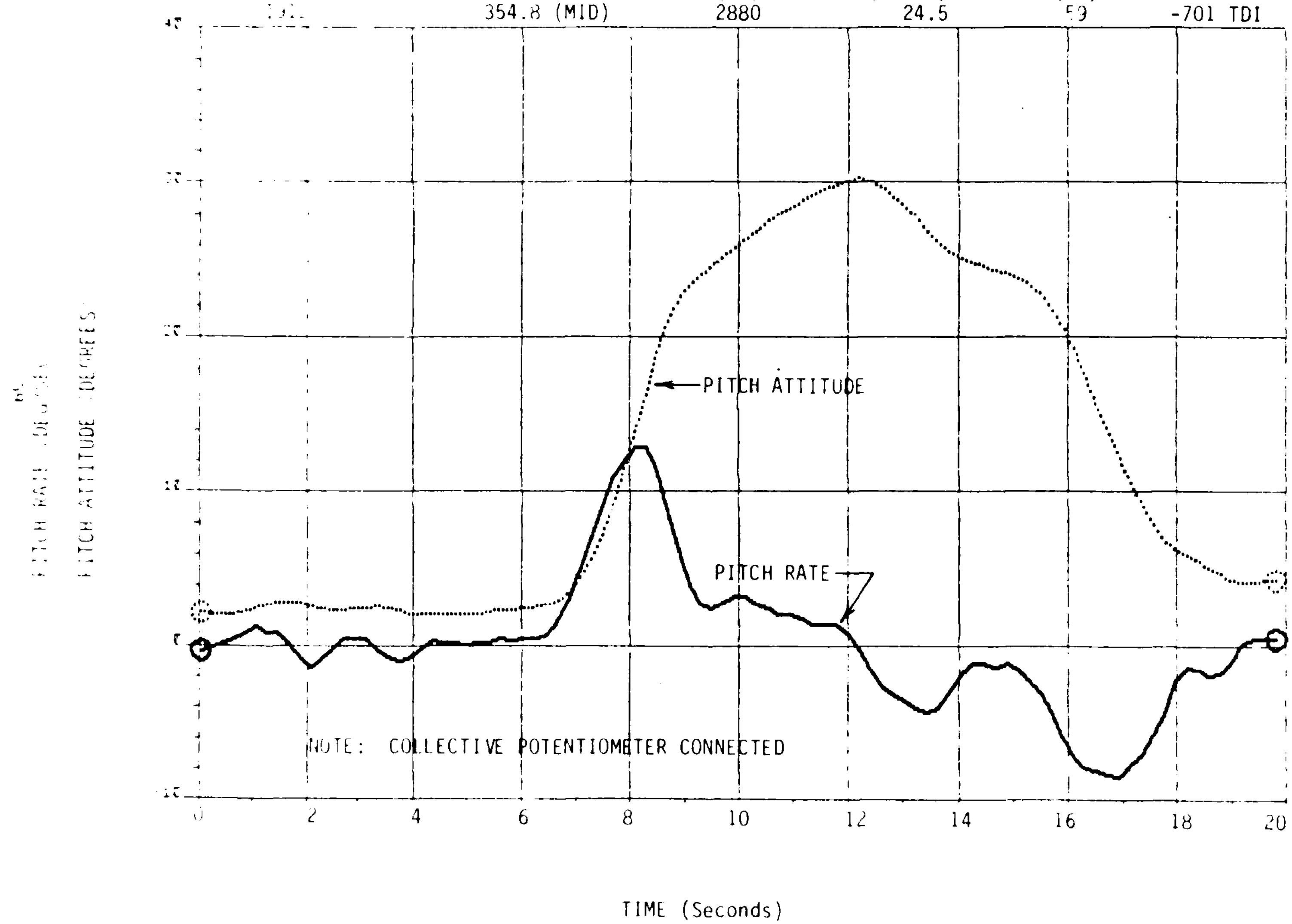


FIGURE 11A

RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

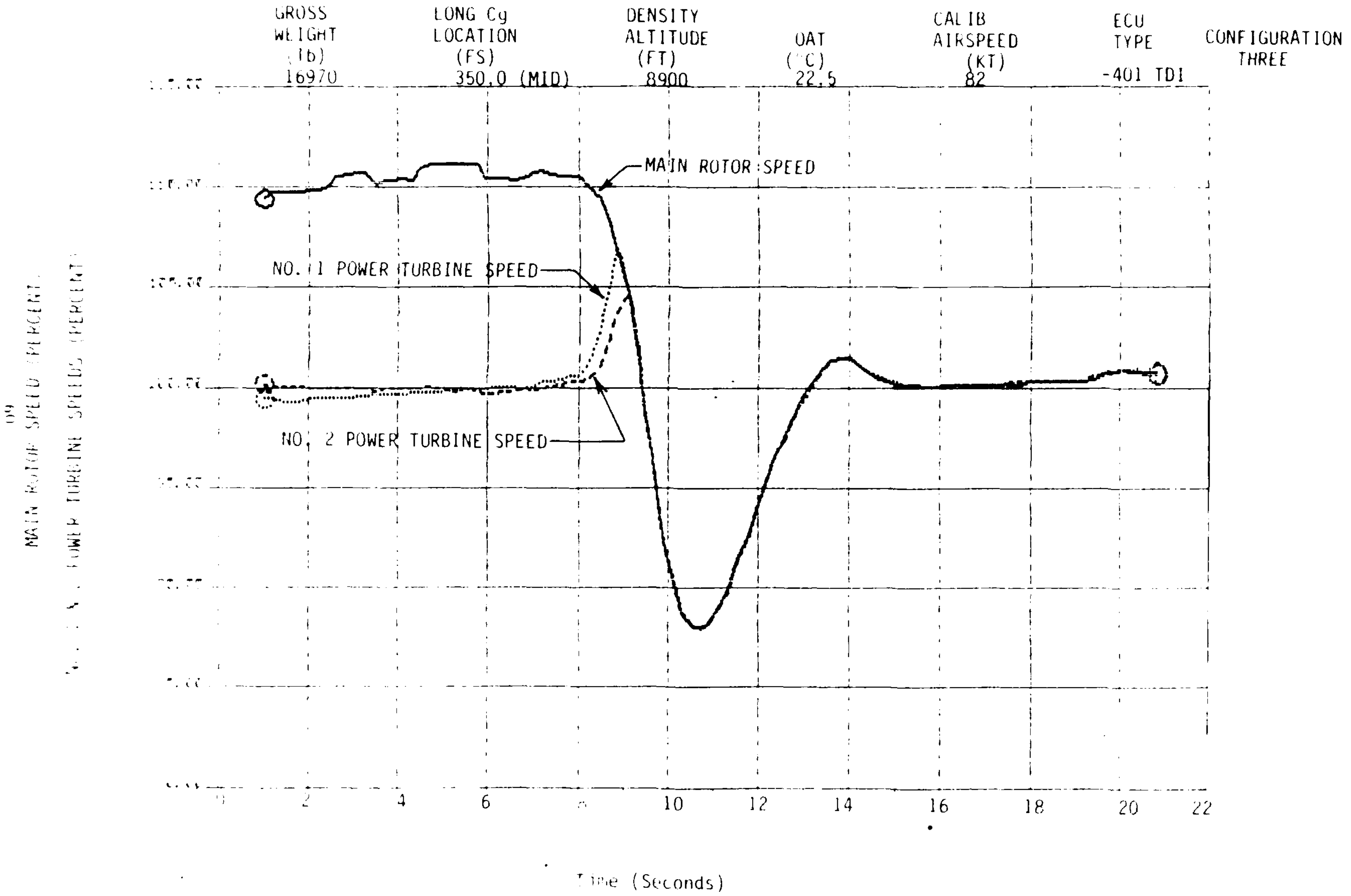


FIGURE 11B

RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

GROSS WEIGHT (LB)	LONG CG LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
16470	350.0 (MID)	8900	22.5	82	-401 TDI	THREE

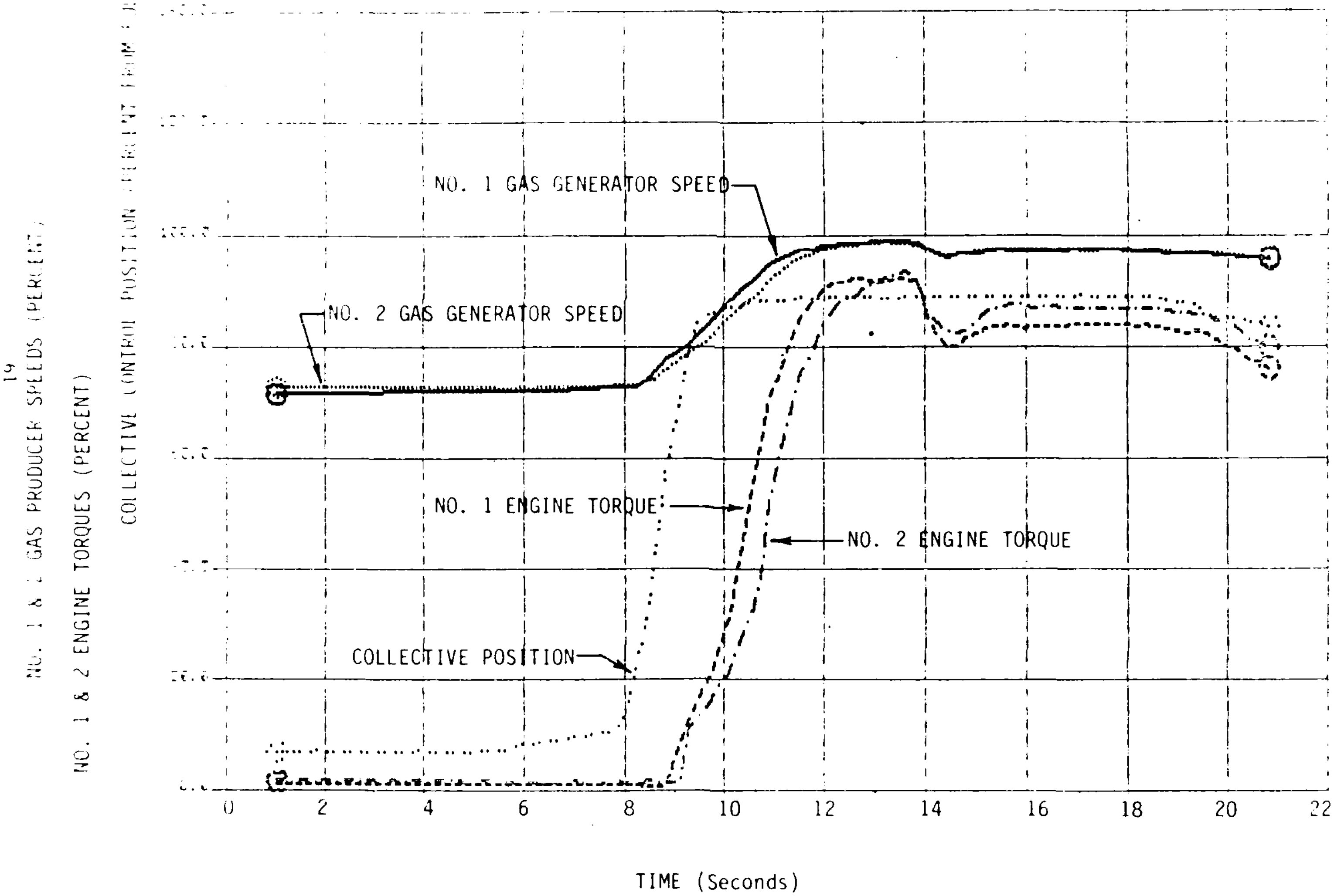


FIGURE 11C

RECOVERY FROM AUTOROTATION
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (°C)	CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION THREE
16970	350.0 (MID)	8900	22.5	82	-401 TDI	

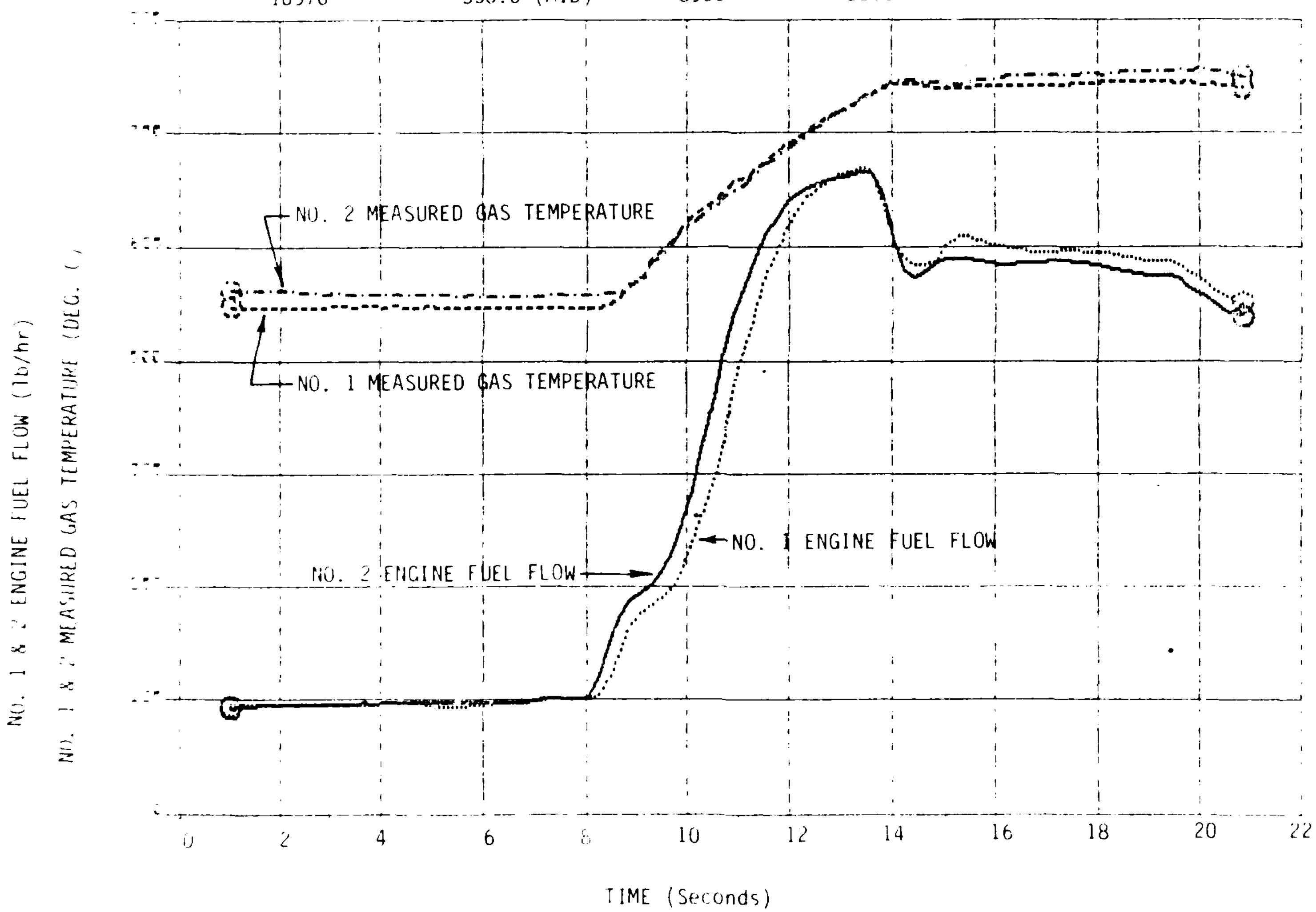


FIGURE 12A

QUICK STOP
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
16701	348.8 (MID)	4870	33.5	82	-401 TDI	THREE

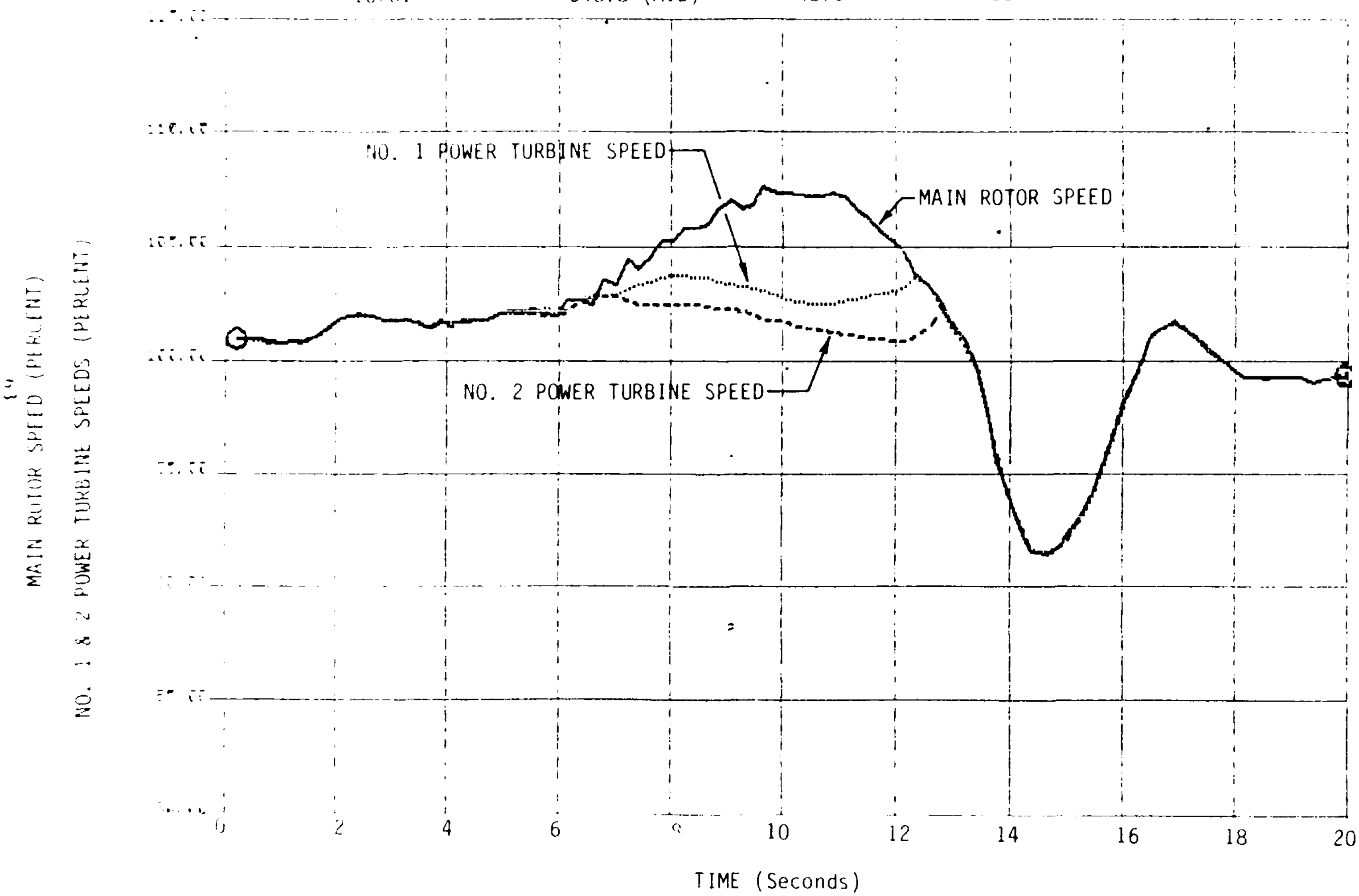


FIGURE 12B

QUICK STOP
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
16701	348.8 (MID)	4870	33.5	82	-401 TDI	THREE

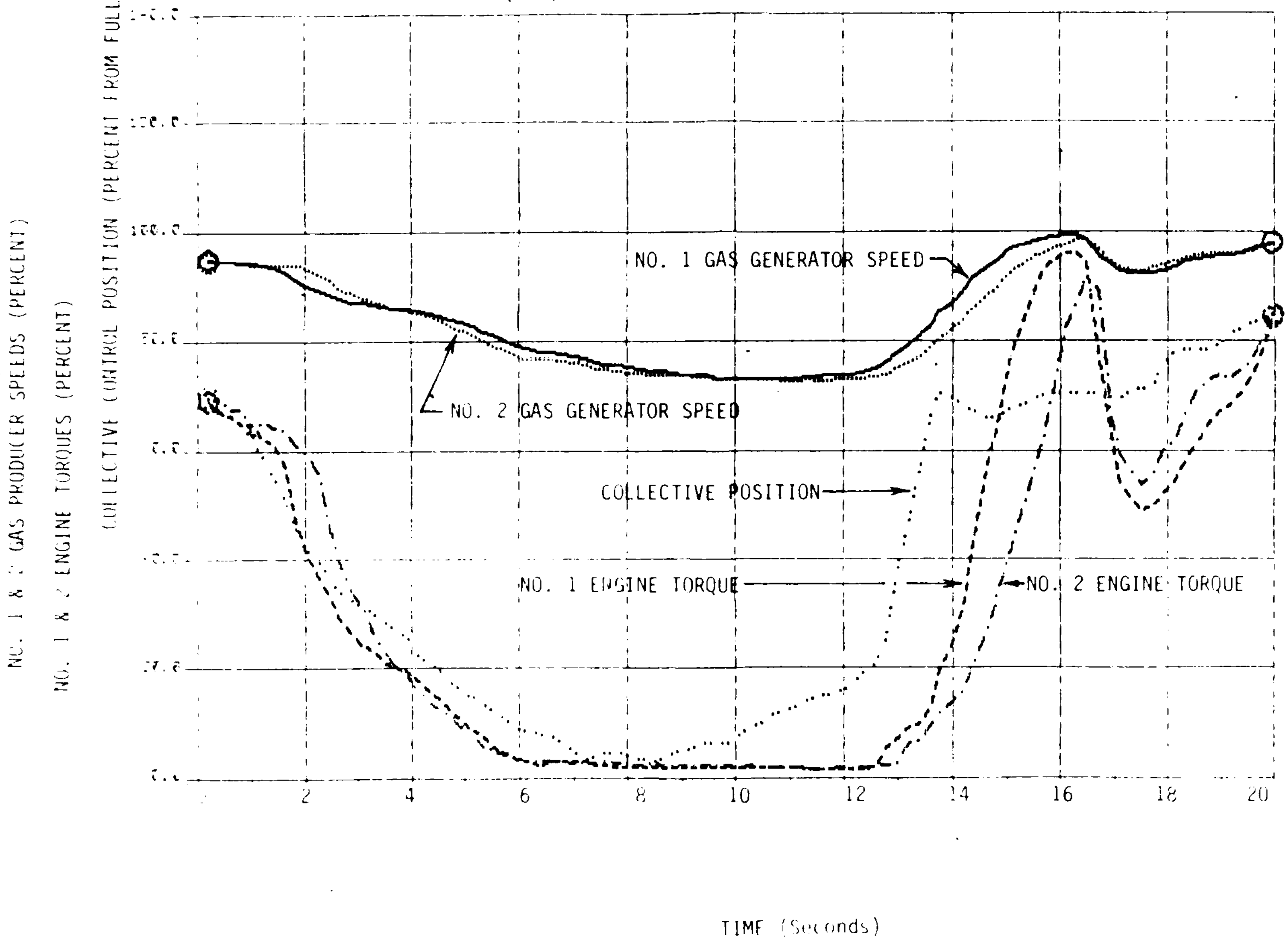


FIGURE 12C

QUICK STOP
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
16701	348.8 (MID)	4870	33.5	82	-401TDI	THREE

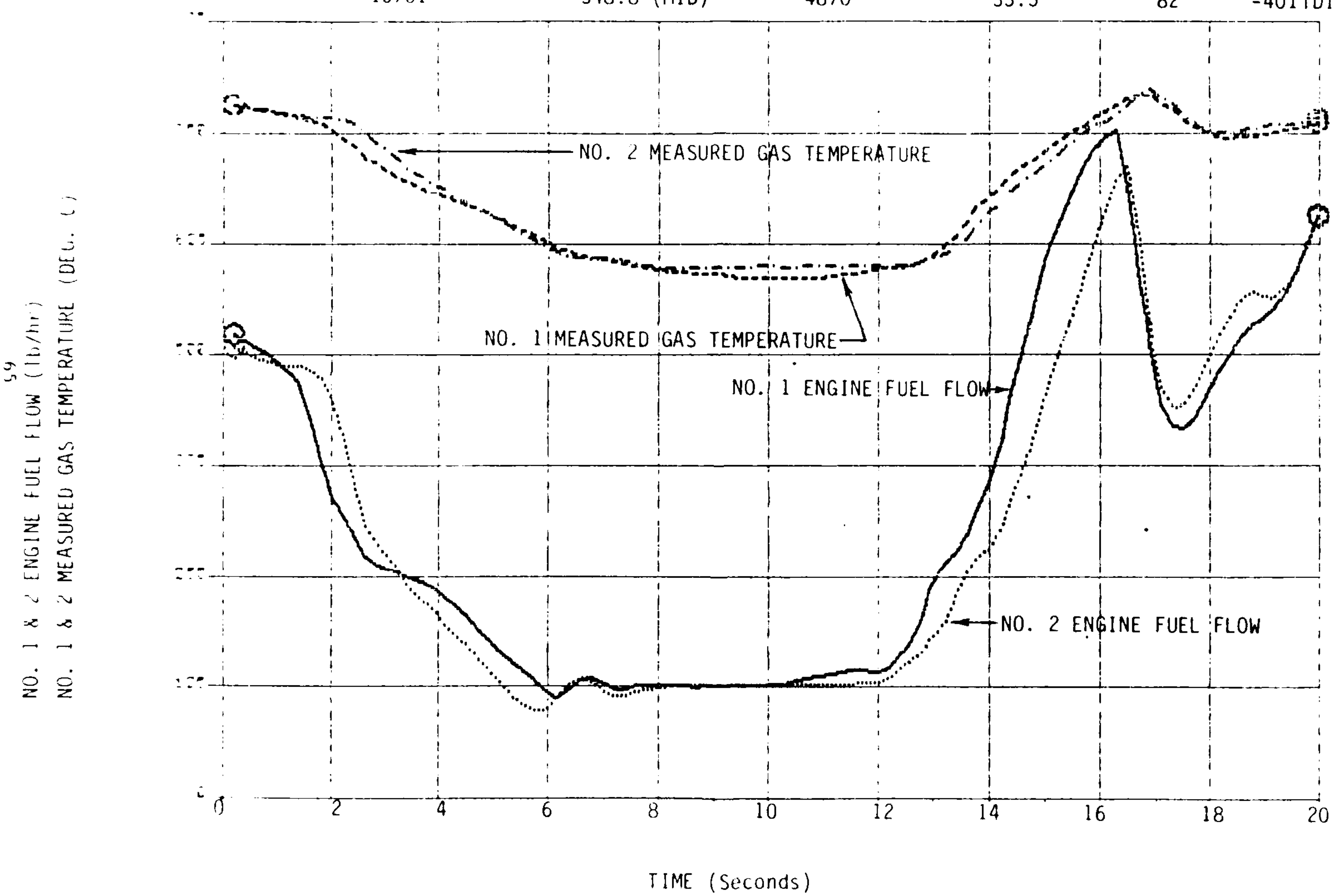


FIGURE 12D

QUICK STOP
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
16701	348.8 (MID)	4870	33.5	82	-401 TDI	THREE

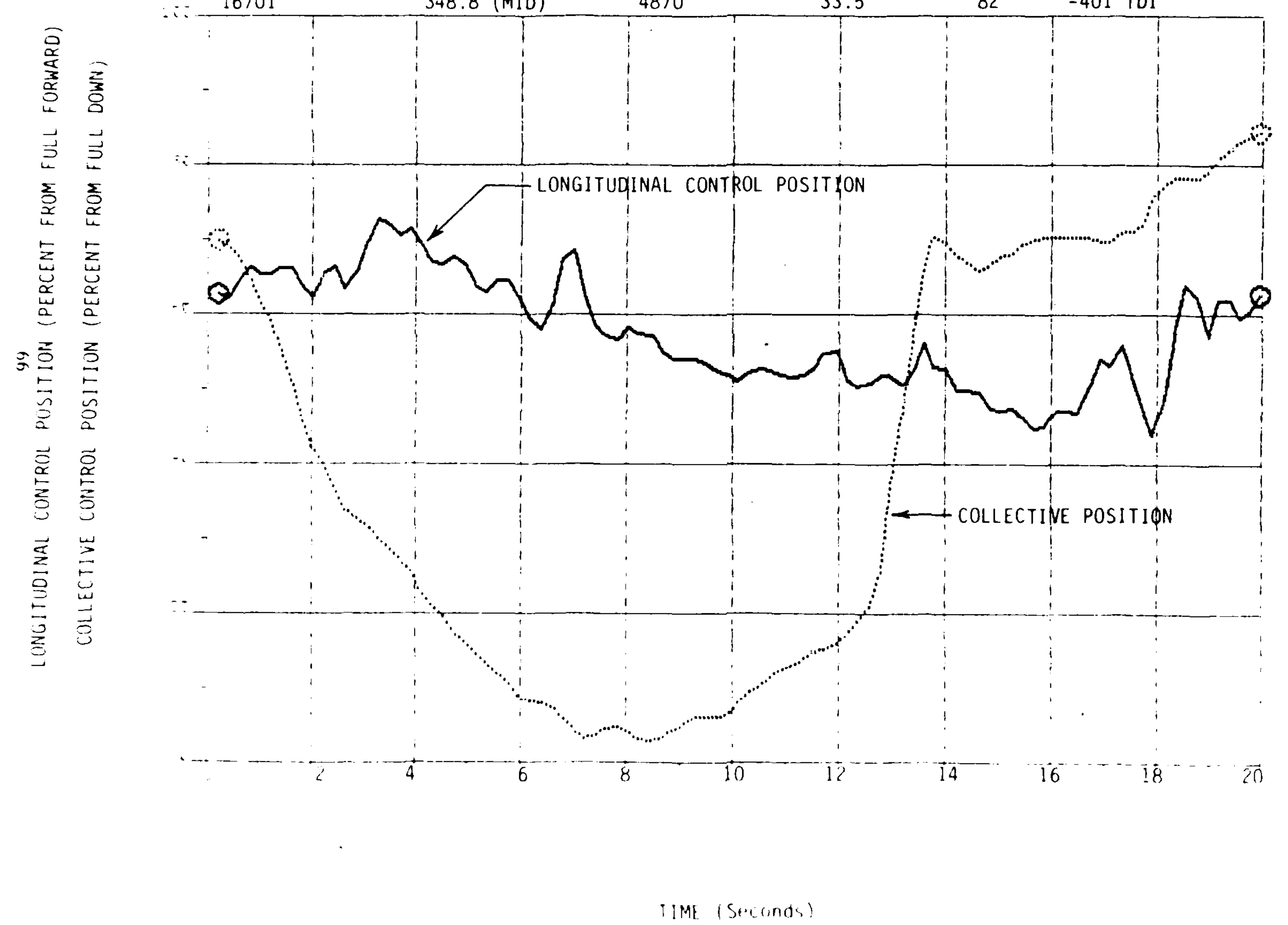


FIGURE 12E

QUICK STOP
HH-60A USAF S/N 82-23718

GROSS WEIGHT (lb)	LONG Cg LOCATION (FS)	DENSITY ALTITUDE (FT)	OAT (DEG C)	ENTRY CALIB AIRSPEED (KT)	ECU TYPE	CONFIGURATION
16701	348.8 (MID)	4870	33.5	82	-401 TDI	THREE

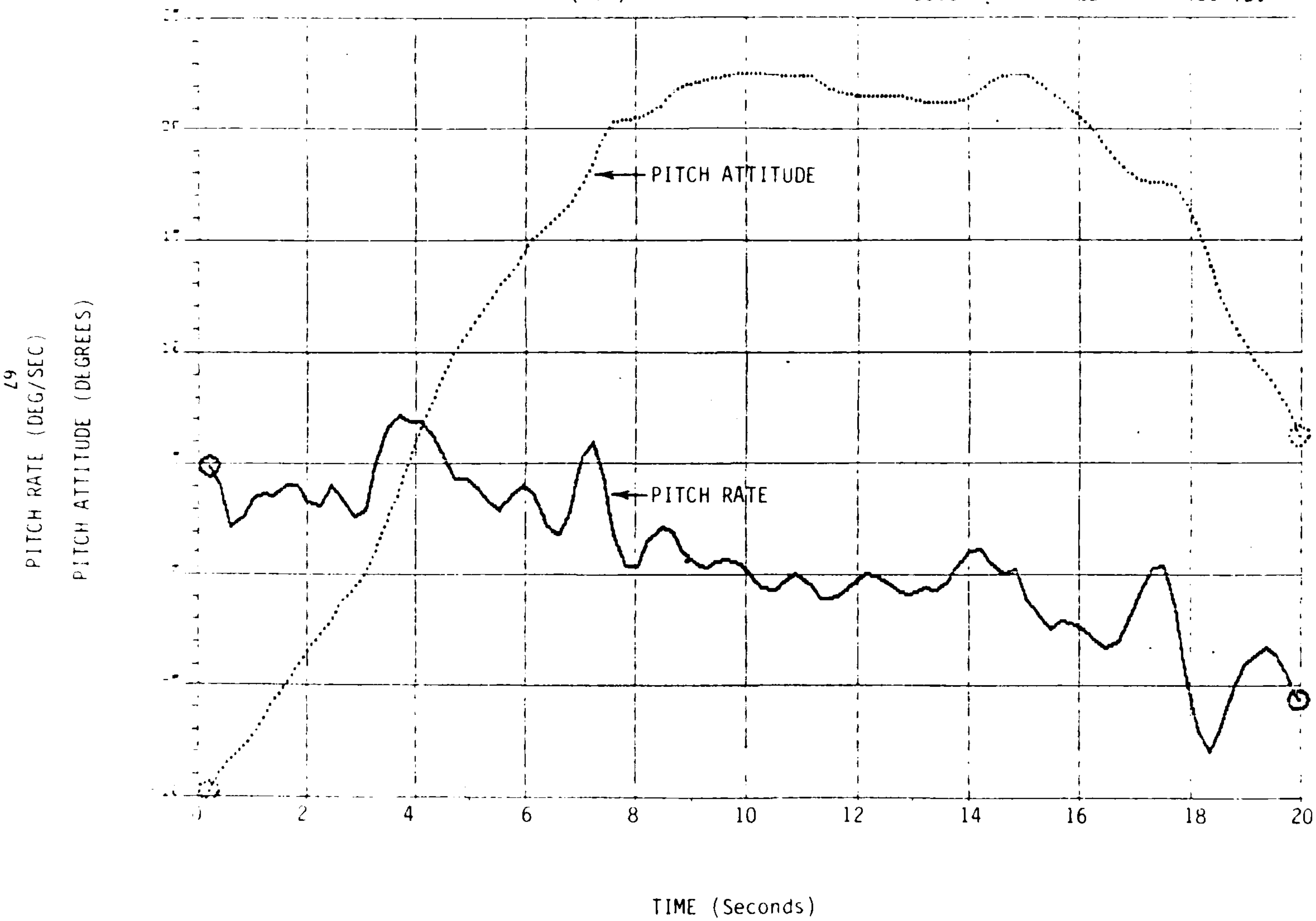


FIGURE 13
JUMP TAKEOFF
UH-60A USA S/N 83-23748

AVG GROSS WEIGHT (LB)	AVG LONG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	CONFIG
16930	352.0(MID)	5170	35.0	FOUR

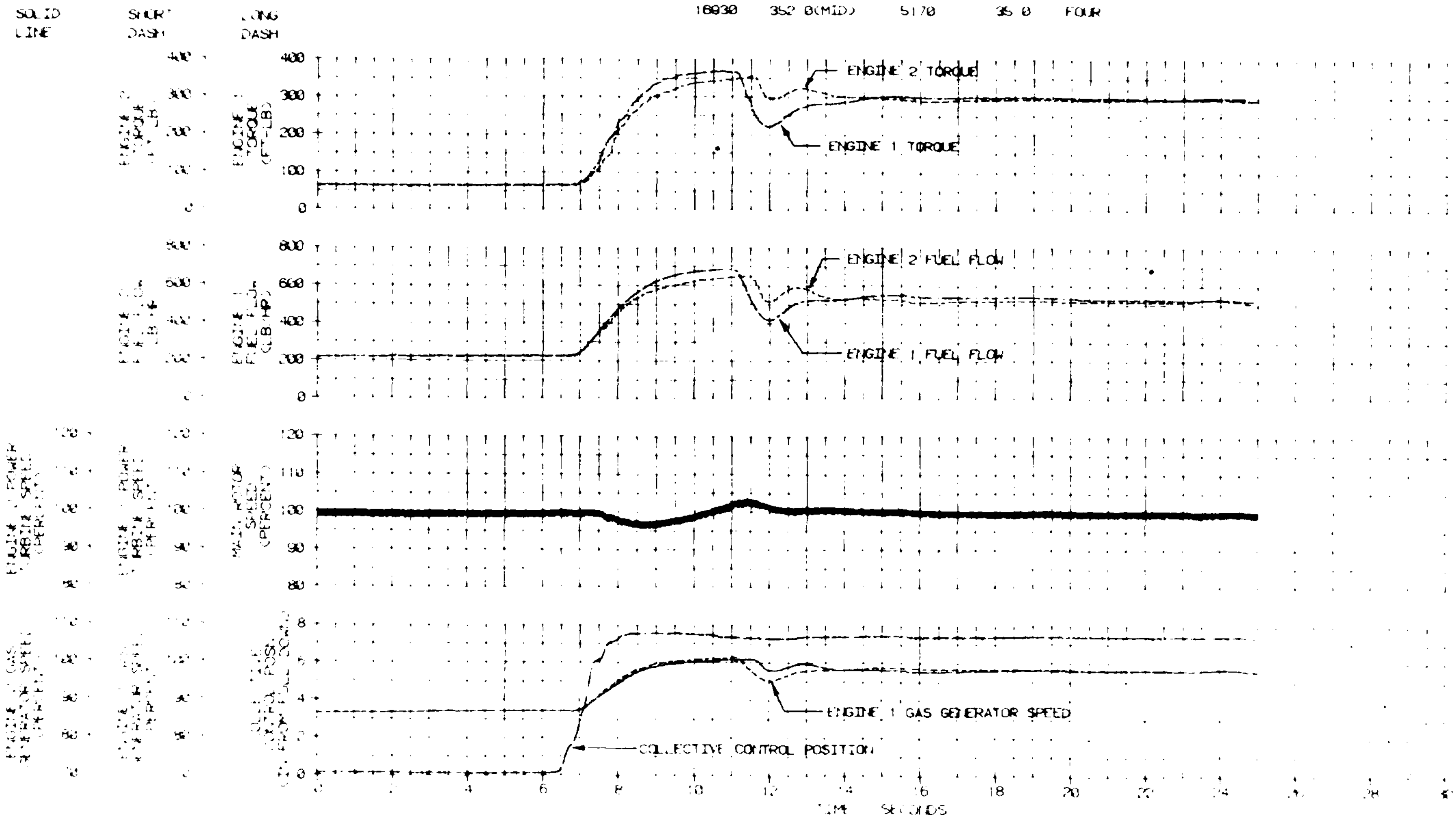


FIGURE 14
RECOVERY FROM AUTOROTATION
UH-60A USA S/N 82-23748

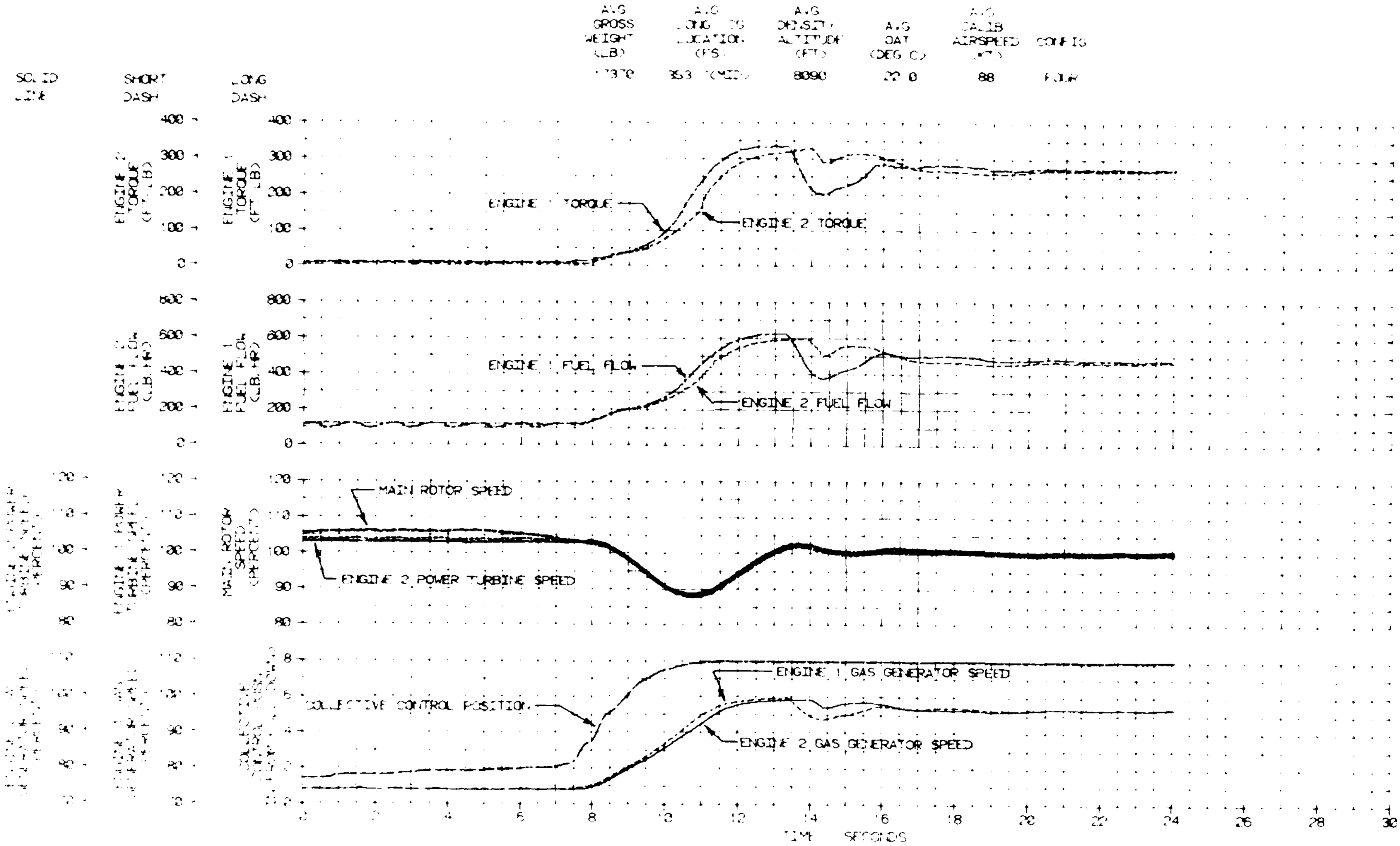


FIGURE 15
QUICK STOP
UH-60A USA S/N 82-23748

AVG GROSS WEIGHT (LB)	AVG LONG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	ENTRY CALIB AIRSPEED (KT)	CONFIG
16990	352 2(MID)	5130	34 5	42	FOUR

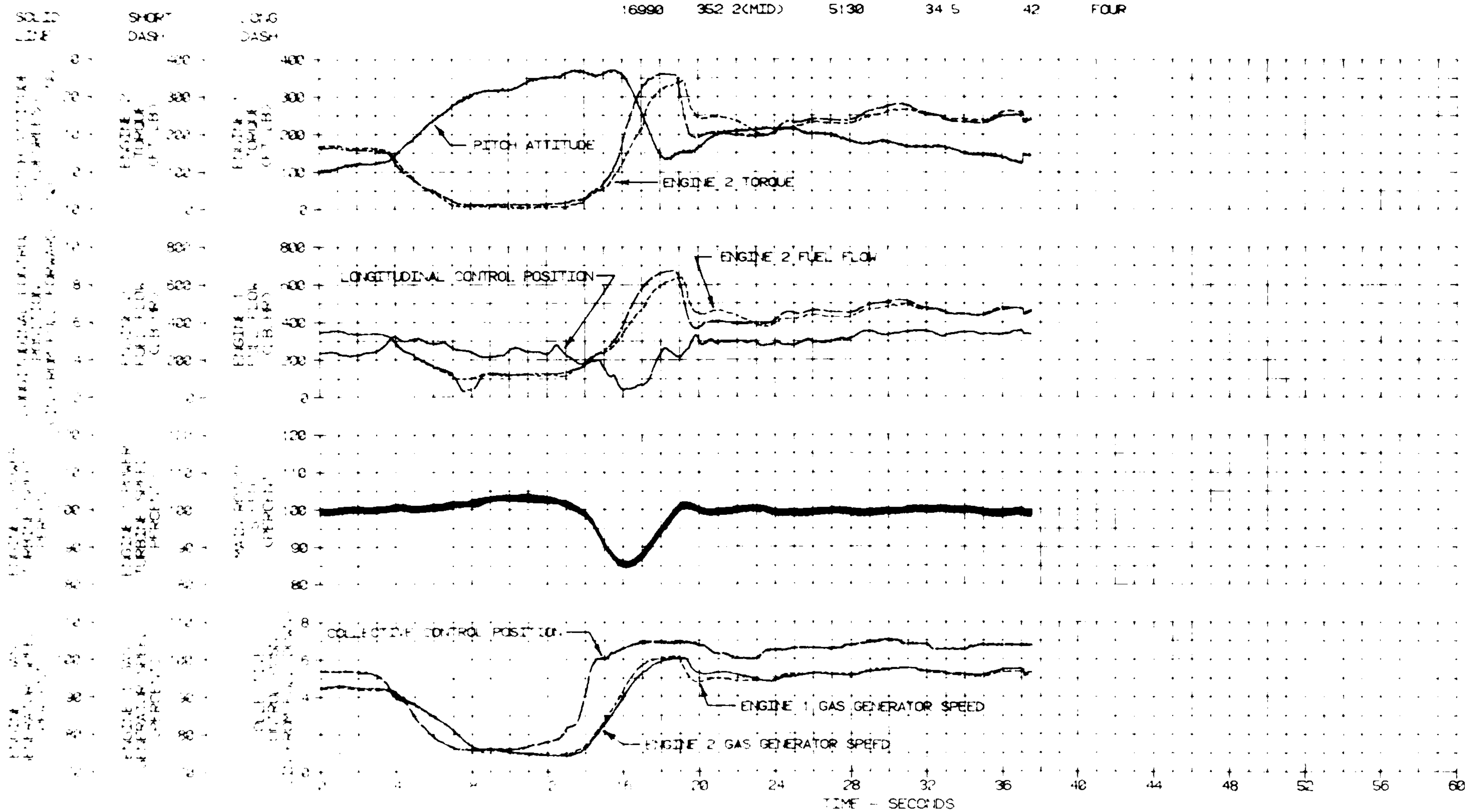
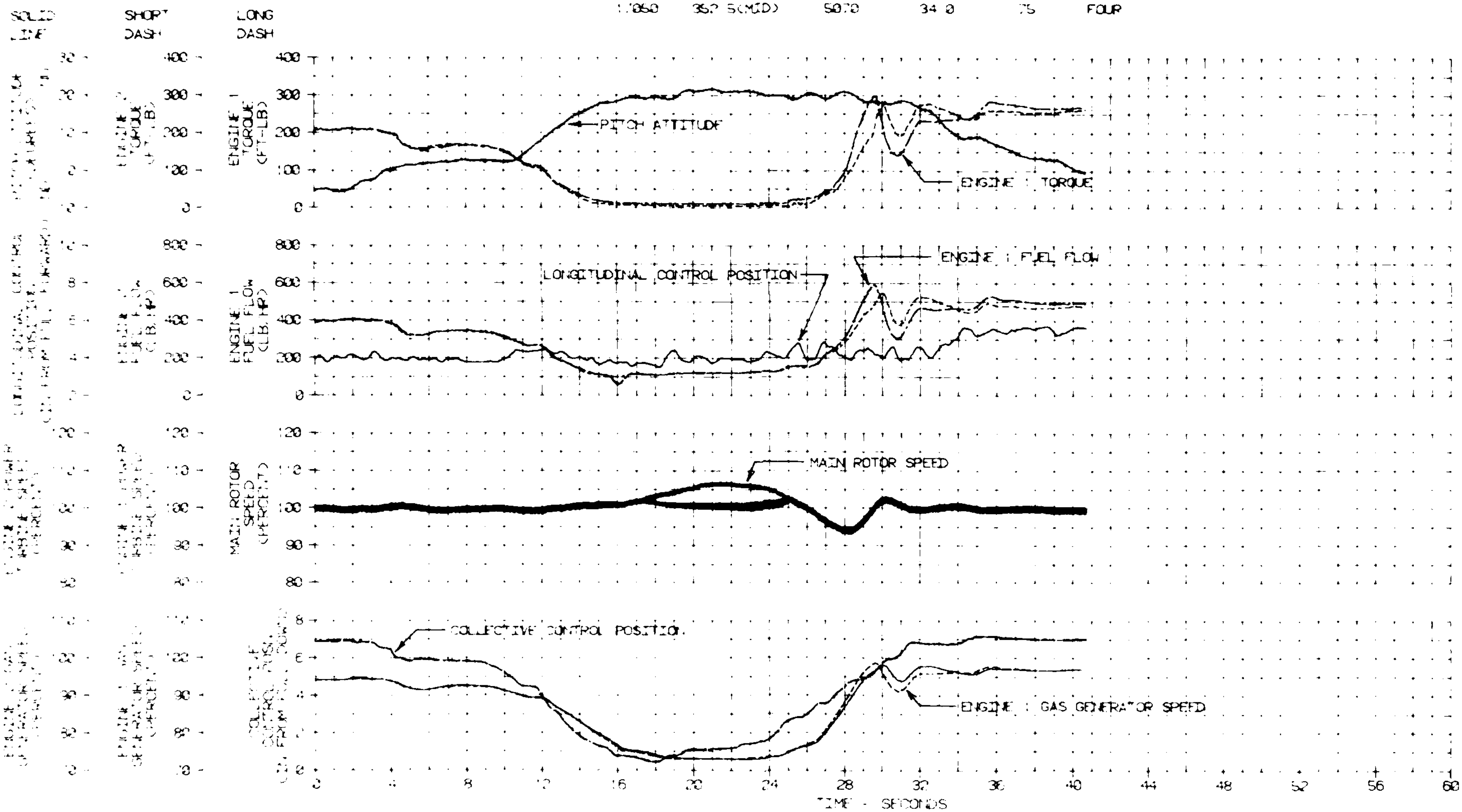


FIGURE 16
QUICK STOP
JUH-60A USA S/N 82-23748

AVG GROSS WEIGHT (LB)	AVG LONG CG LOCATION (FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	ENTRY CALIB AIRSPEED (KT)	CONFIG
17050	352.5(MID)	5070	34.0	75	FOUR



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